# Septic Shock

## DIU Echocardiographie
## Paris 2006

Michel Slama
Amiens
France

# Epidemiology

- 240 cases/ 100 000 USA between 1979-2000 (Martin G, NEJM 2003)
- 10 admissions/100 ICU admission (Annane D, AJRCCM 2003)
- Mortality rate between 30-60%
  - despite new treatments : corticosteroids, activated protein C
  - Explanation: more aged and severe patients

# Diagnostic and monitoring techniques used in septic shock patients

- Swan-Ganz catheter:
  - 37% in septic shock are managed with SG catheter (Annane D, AJRCCM 2003)
  - Invasive tool but two studies demonstrated
    - French multicentrique study in septic shock and pulmonary oedema : no decrease in the mortality rate (Richard Ch, JAMA 2004)
    - In high risk surgical patients (Sandham), no decrease in the mortality rate.
- Autres : Picco, Doppler oesophagien

# Early Use of the Pulmonary Artery Catheter and Outcomes in Patients With Shock and Acute Respiratory Distress Syndrome

## A Randomized Controlled Trial


Christian Richard, MD
Josiane Warszawski, MD, PhD
Nadia Anguel, MD
Nicolas Deye, MD
Alain Combes, MD
Didier Barnoud, MD
Thierry Boulain, MD
Yannick Lefort, MD
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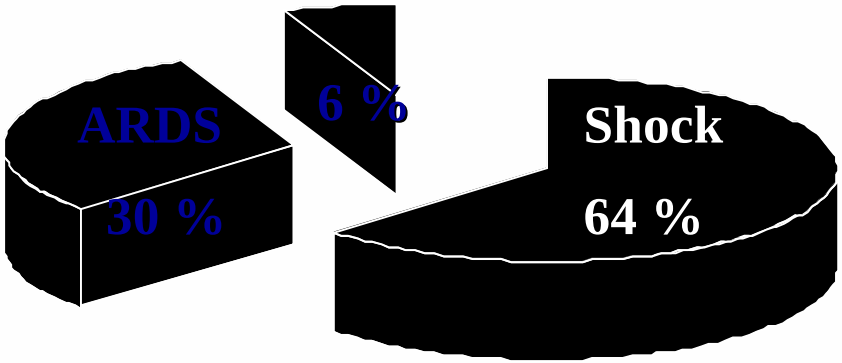
Frederic Baud, MD, PhD
Alexandre Boyer, MD
Laurent Brochard, MD, PhD
Jean-Louis Teboul, MD, PhD
for the French Pulmonary Artery Catheter Study Group


**676 patients**

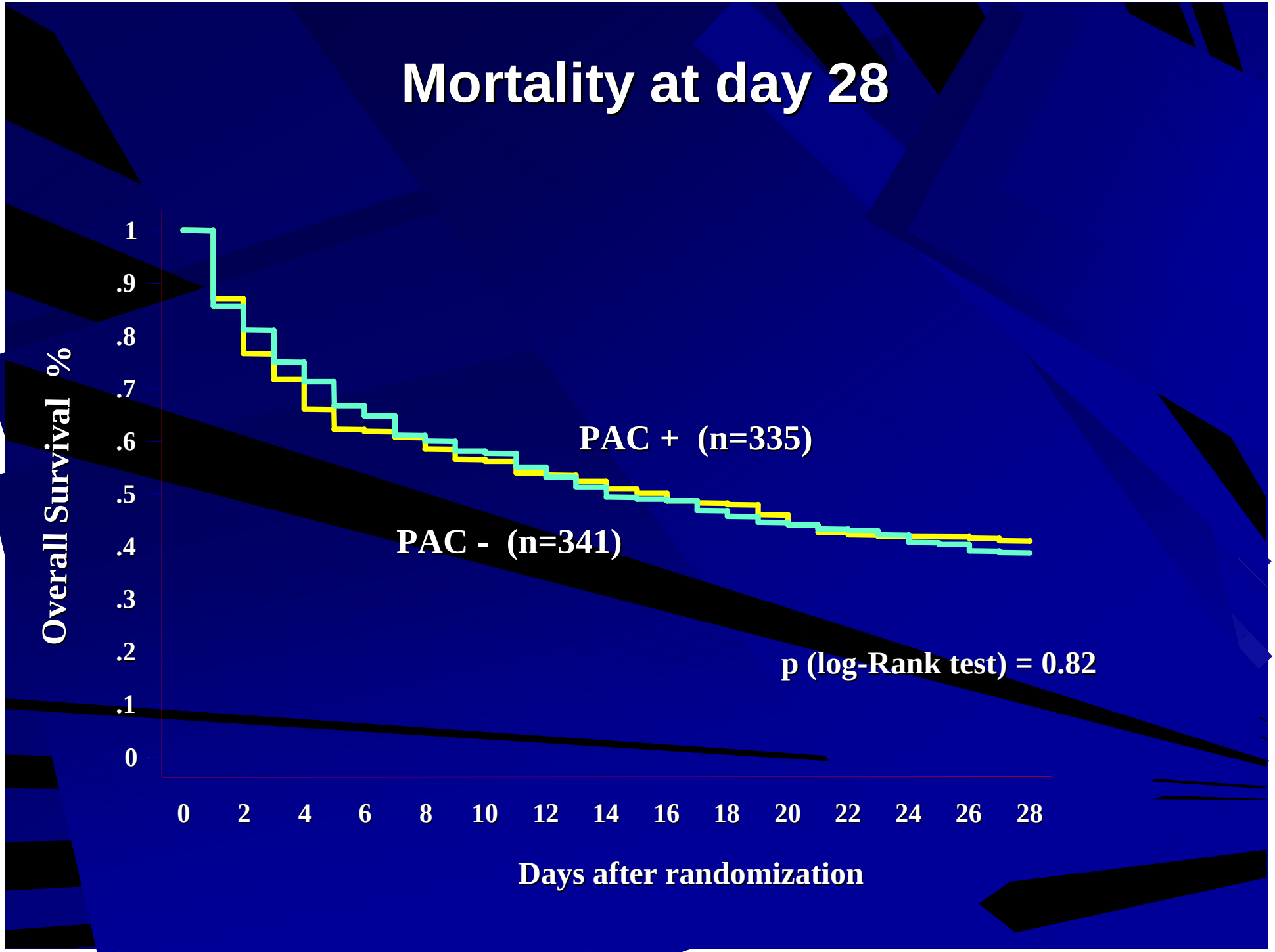
**Shock + ARDS**





*JAMA 2003, 290:2717-20*

# Mortality at day 28

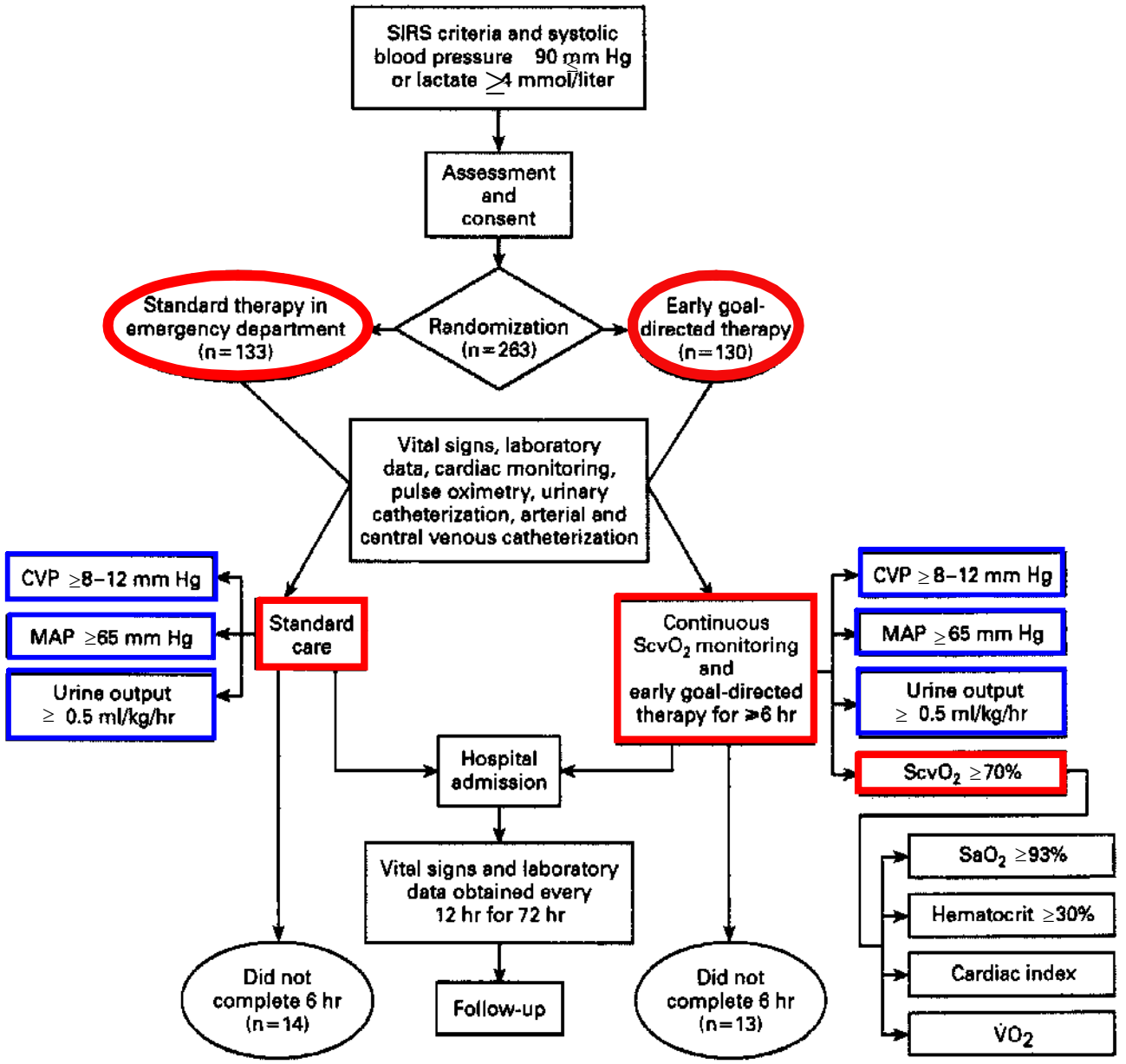


The New England Journal of Medicine

# EARLY GOAL-DIRECTED THERAPY IN THE TREATMENT OF SEVERE SEPSIS AND SEPTIC SHOCK

EMANUEL RIVERS, M.D., M.P.H., BRYANT NGUYEN, M.D., SUZANNE HAVSTAD, M.A., JULIE RESSLER, B.S., ALEXANDRIA MUZZIN, B.S., BERNHARD KNOBLICH, M.D., EDWARD PETERSON, PH.D., AND MICHAEL TOMLANOVICH, M.D., FOR THE EARLY GOAL-DIRECTED THERAPY COLLABORATIVE GROUP*

Rivers et al. *N Engl J Med* 2001;345:1368-77

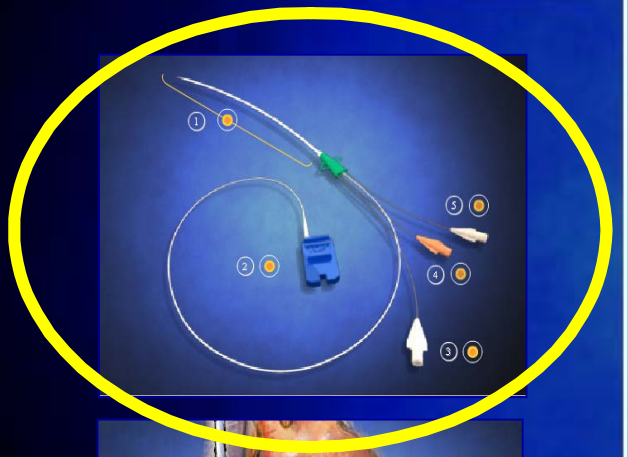



Rivers NEJM 2001

# Early Treatment Protocol

Supplemental oxygen ± endotracheal intubation and mechanical ventilation

Central venous and arterial catheterization



Sedation, paralysis (if intubated), or both

CVP
- <8 mm Hg → Crystalloid / Colloid
- 8-12 mm Hg

MAP
- <65 mm Hg → Vasoactive agents
- >90 mm Hg
- ≥ 65 and ≤ 90 mm Hg

$ScvO_2$
- < 70% → Transfusion of red cells until hematocrit≥30%
- >70%
- ≥70%

Inotropic agents (<70%)

Goals achieved
- No → Sedation, paralysis (if intubated), or both
- Yes → Hospital Admission

Rivers NEJM 2001

Une unité spécifique de prise en charge (9 lits) 1 médecins, 2 internes, 3 infirmières

**TABLE 3.** KAPLAN–MEIER ESTIMATES OF MORTALITY AND CAUSES OF IN-HOSPITAL DEATH.*

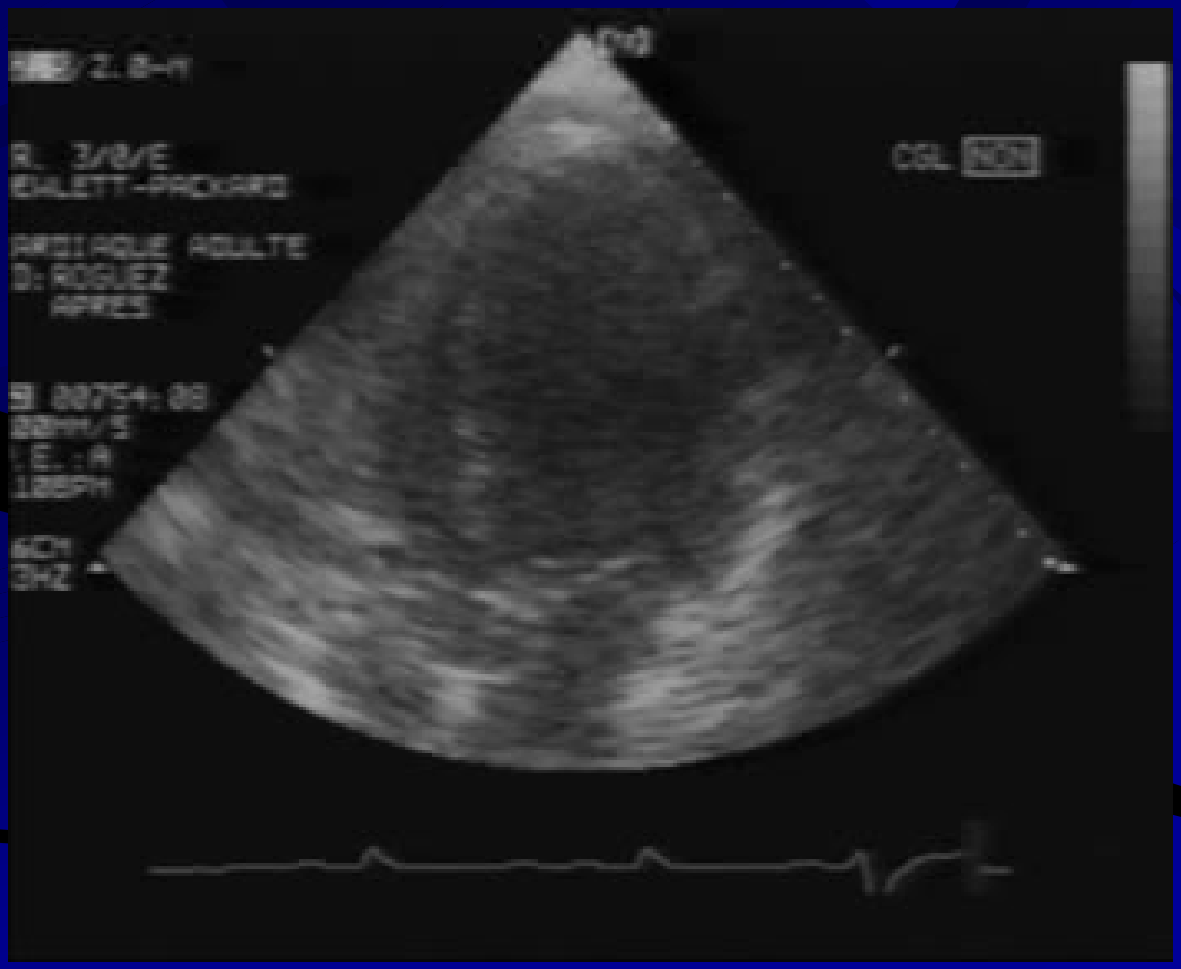
| VARIABLE | STANDARD THERAPY (N=133) | EARLY GOAL-DIRECTED THERAPY (N=130) | RELATIVE RISK (95% CI) | P VALUE |
|---|---|---|---|---|
| | no. (%) | | | |
| In-hospital mortality† | | | | |
| All patients | 59 (46.5) | 38 (30.5) | 0.58 (0.38–0.87) | 0.009 |
| Patients with severe sepsis | 19 (30.0) | 9 (14.9) | 0.46 (0.21–1.03) | 0.06 |
| Patients with septic shock | 40 (56.8) | 29 (42.3) | 0.60 (0.36–0.98) | 0.04 |
| Patients with sepsis syndrome | 44 (45.4) | 35 (35.1) | 0.66 (0.42–1.04) | 0.07 |
| 28-Day mortality† | 61 (49.2) | 40 (33.3) | 0.58 (0.39–0.87) | 0.01 |
| 60-Day mortality† | 70 (56.9) | 50 (44.3) | 0.67 (0.46–0.96) | 0.03 |
| Causes of in-hospital death‡ | | | | |
| Sudden cardiovascular collapse | 25/119 (21.0) | 12/117 (10.3) | — | 0.02 |
| Multiorgan failure | 26/119 (21.8) | 19/117 (16.2) | — | 0.27 |

Rivers NEJM 2001

# Echocardiographic examination

- Transthoracic vs transesophageal echocardiography
  - TTE
    - More than 80% of clinical problems solved
    - Non invasive technique
    - Easy to perform
    - Echogenicity
    - Cost-effectiveness
  - TEE
    - Semi invasive
    - Monitoring technique
    - Side effects (mortality rate <0,01%) (Daniel)

# Echogénicité



# Impact thérapeutique de l'ETO

| Auteurs (années) | Patients (n) | Impact thérapeutique (%) |
|---|---|---|
| Oh (1990) | 51 | 24 |
| Vignon (1994) | 96 | 44 |
| Heidenreich (1995) | 61 | 68 |
| Poelaert (1995) | 108 | 43 |
| Sohn (1995) | 124 | 52 |
| Slama (1996) | 61 | 20 |
| Colreavy (2002) | 255 | 34 |

Aucune étude n'a démontré une amélioration du pronostic, de la morbidité, ni de la mortalité en réanimation.

# Complications de l'ETO

- Réanimation
  - 20% saignements mineurs de la cavité buccale
  - 4-5% de complications (Slama, Oh, Pearson)
  - Perforation oesophagienne (petite taille, radiothérapie).
  - Embolie périphérique (anévrysme aortique, thrombus de l'OG).
  - Fractures cervicales.
  - Autres : tachycardie, détresse respiratoire, état de mal épileptique, vomissements. Pas séquelles de ces complications.

Le plus souvent excellente tolérance

# Physiopathology

- Several mechanisms induce circulatory failure
  - Absolute decrease in central blood volume
  - Relative decrease in central blood volume
  - Severe peripherical vasodilation
  - Systolic and diastolic dysfunction of left ventricle
  - Right ventricular failure

Etat de choc d'allure septique

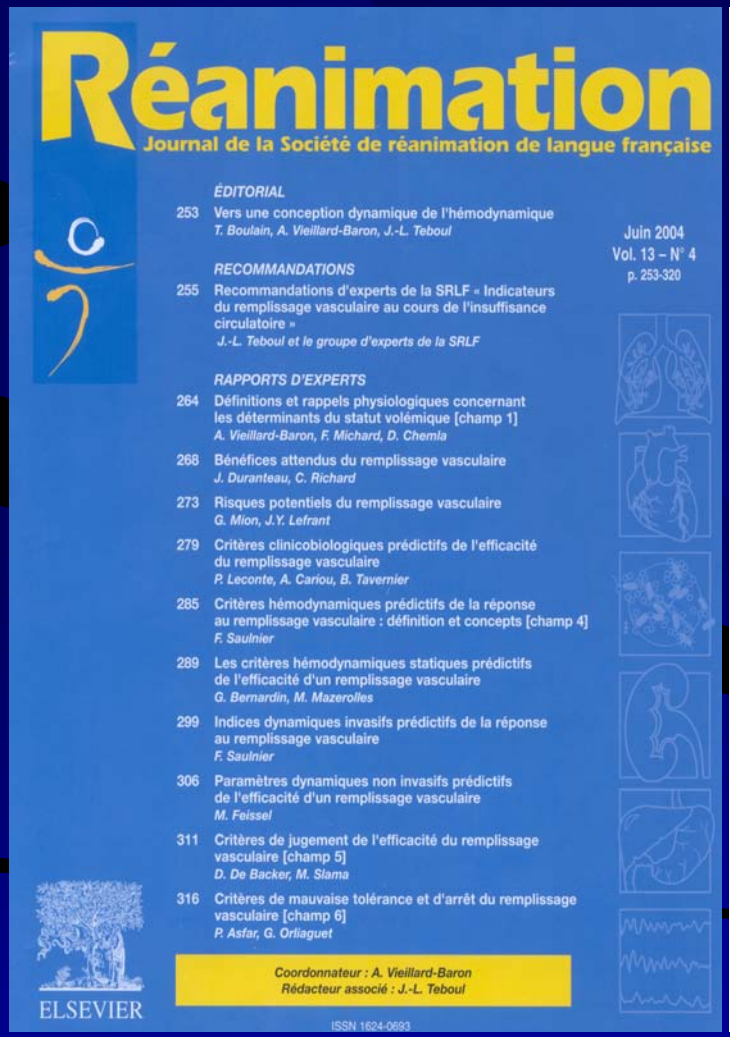
Cathéter radial et Echocardiographie

Besoin en remplissage

## « What are your indicators for volume replacement (diagnostic tools) ? »

Boldt et al. Intensive Care Med 1998; 24:147-151

| | |
|---|---|
| **PVC** | **93 %** |
| **PAPO** | **58 %** |
| ETO | 2 % |




Réanimation

Journal de la Société de réanimation de langue française





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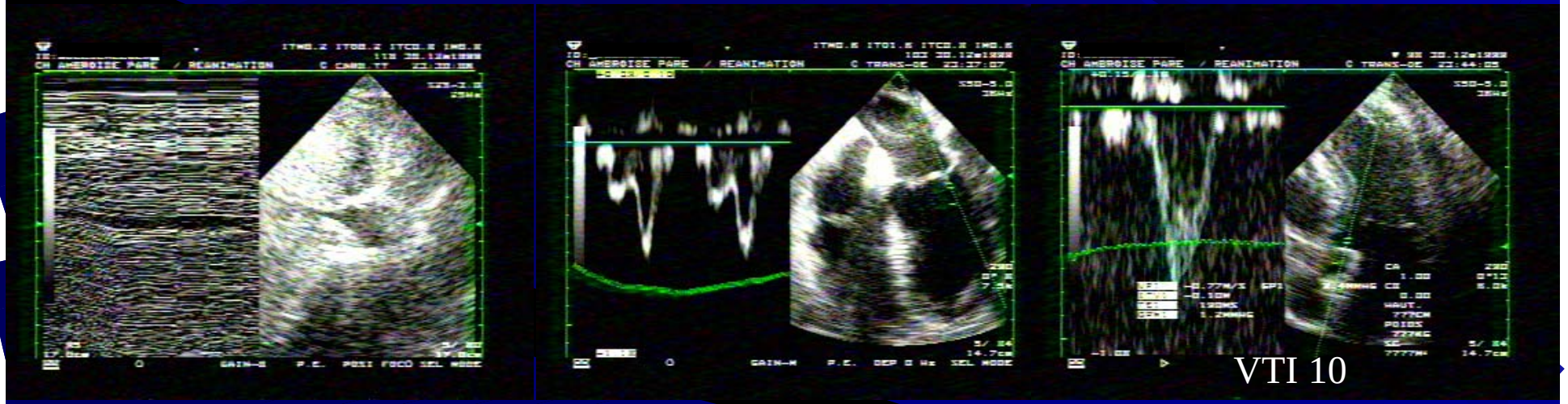
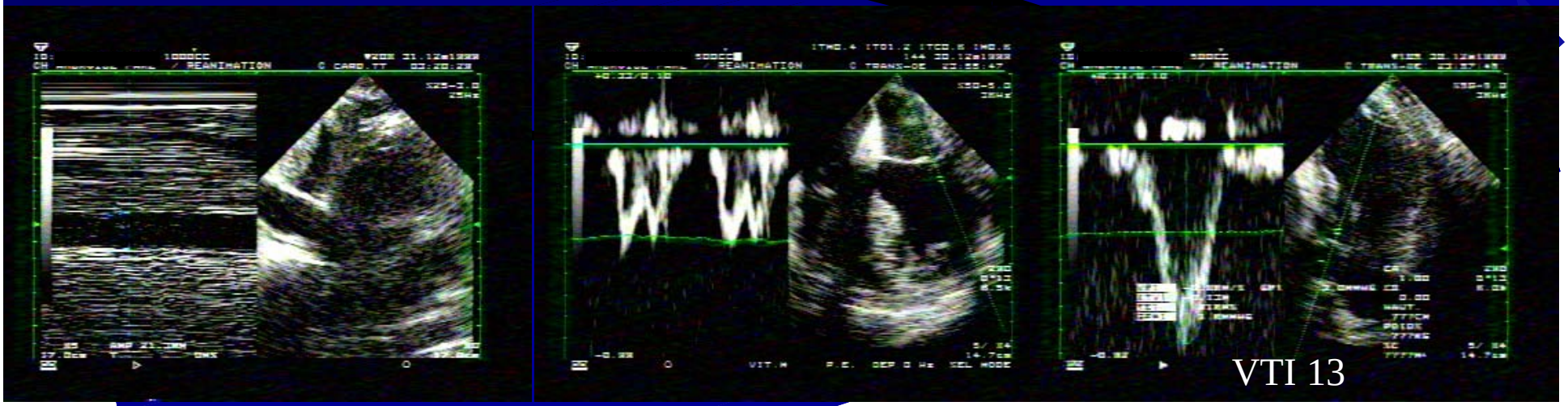
Michel Slama (Amiens)
Benoît Tavernier (Lille)
Antoine Vieillard-Baron (Boulogne-Billancourt)

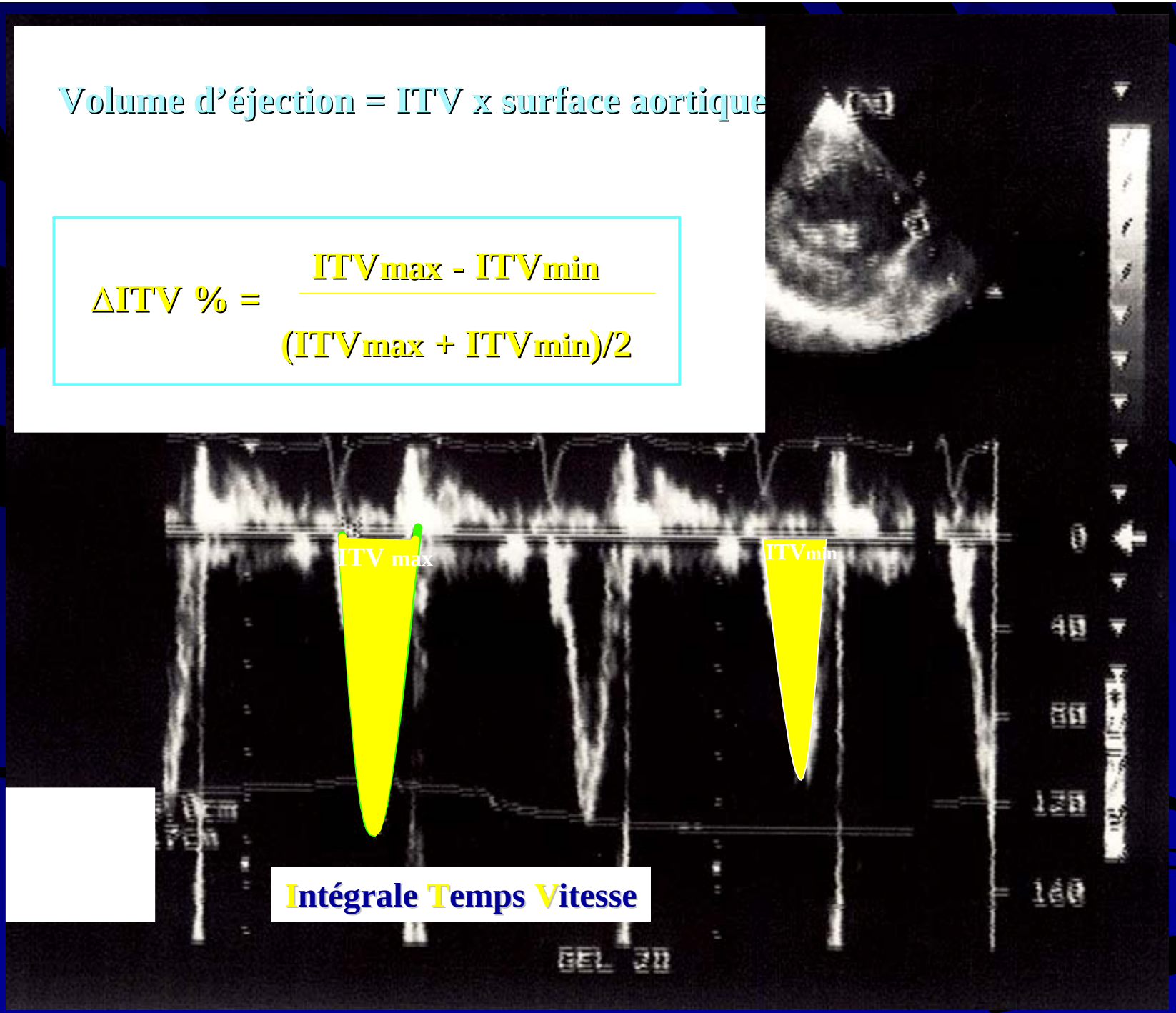
« En dehors de situations caricaturales (pressions très basses ou très élevées), l'estimation des pressions de remplissage à l'échocardiographie ne permet pas de prédire la réponse au remplissage »



Volume d'éjection = ITV x surface aortique

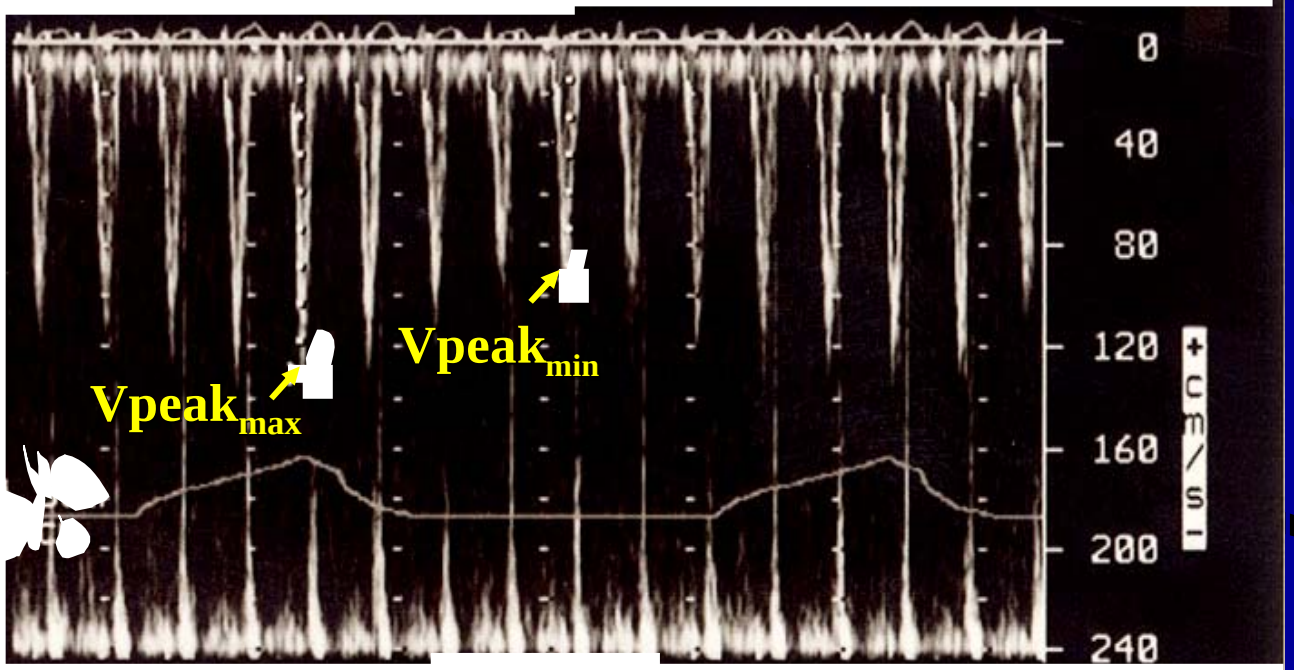
$$\Delta ITV\ \% = \frac{ITV_{max} - ITV_{min}}{(ITV_{max} + ITV_{min})/2}$$

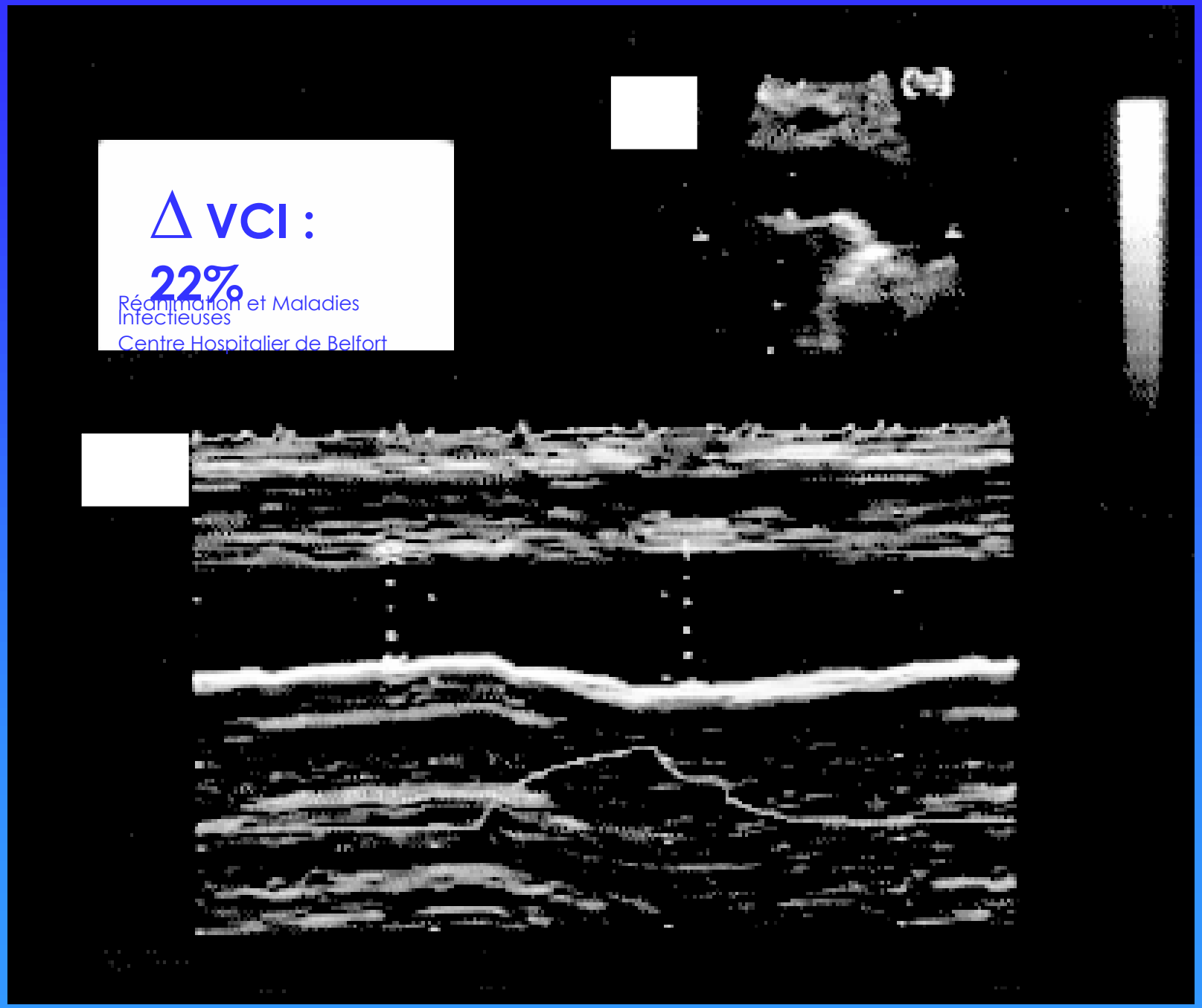


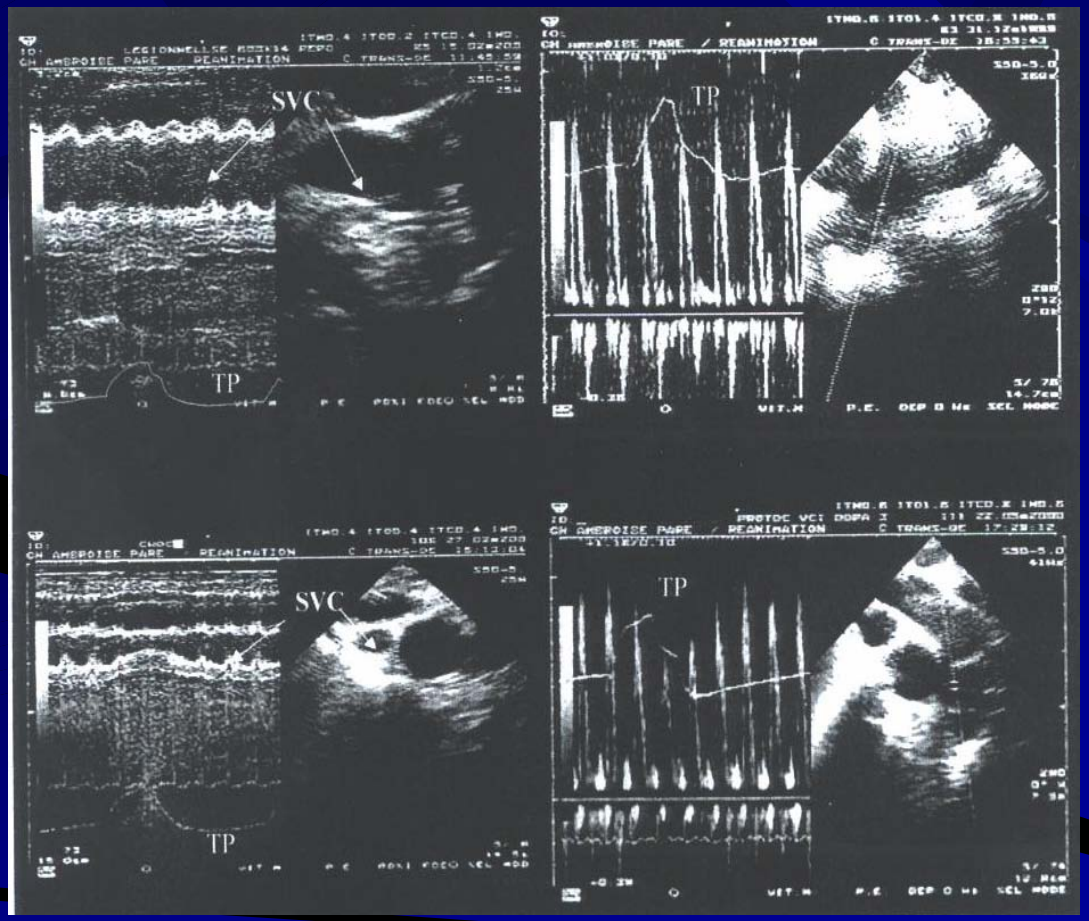
## $\Delta Vpeak$ : 33 %

$$\Delta Vpeak = \frac{Vpeak_{max} - Vpeak_{min}}{(Vpeak_{max} + Vpeak_{min})/2}$$

Cardiac output
will increase
by more than 40 %
after fluid infusion



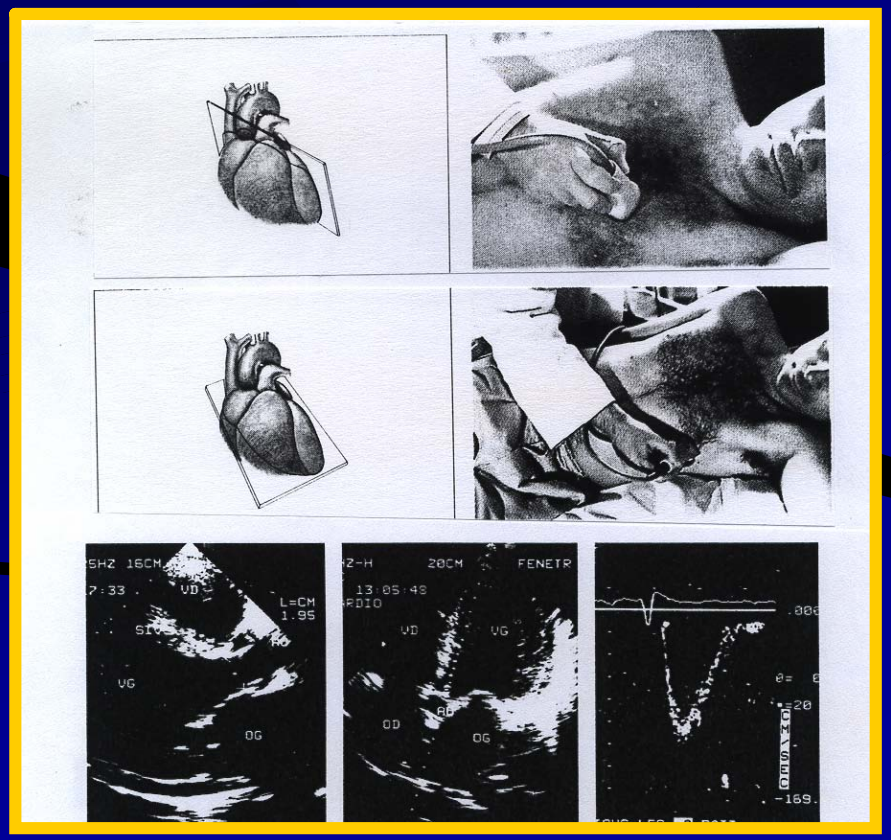

Δ VCI :
22%
Réanimation et Maladies Infectieuses
Centre Hospitalier de Belfort




Vieillard-Baron A Anesthesiology 2001;95:1083-8

# How to perform echocardiographic examination in septic shock patient?

- Cardiac output TTE:



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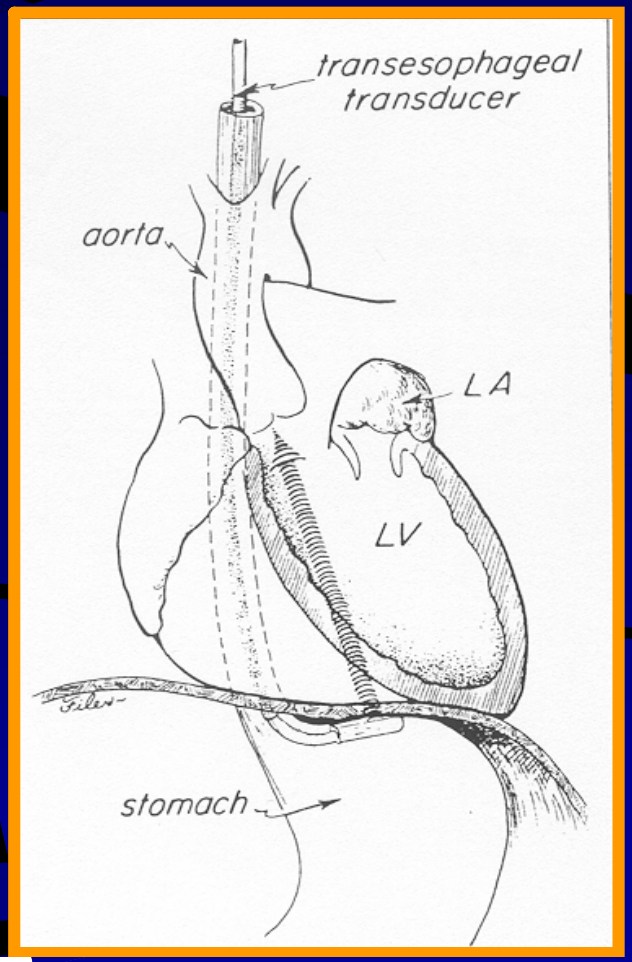
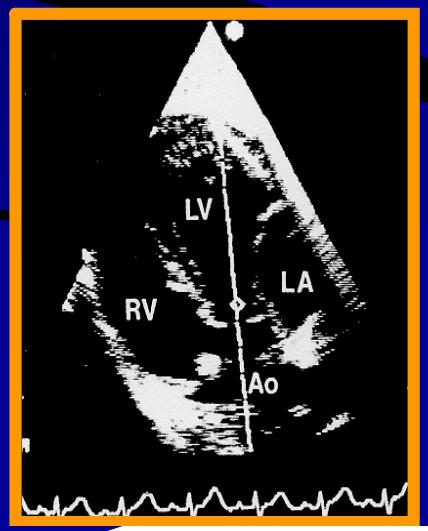
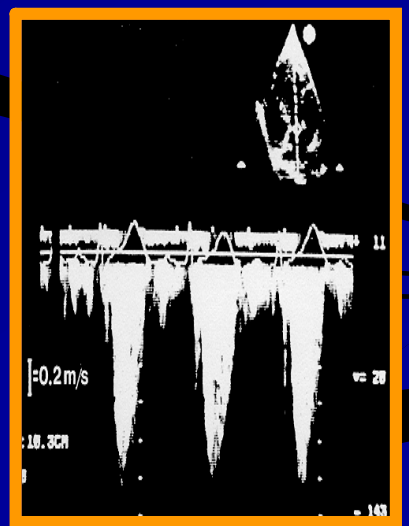
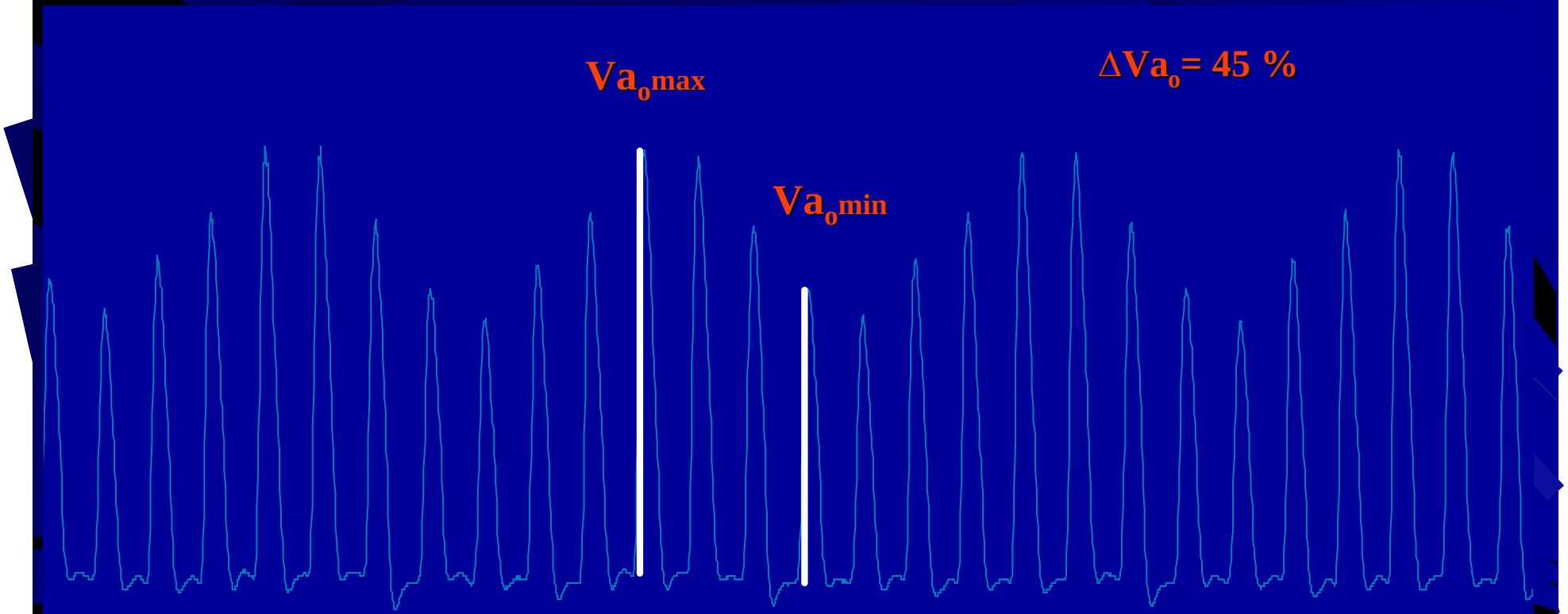






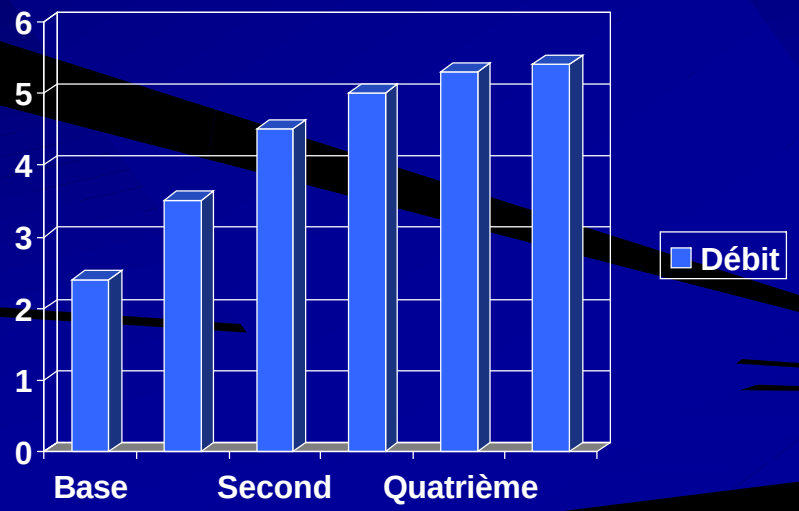



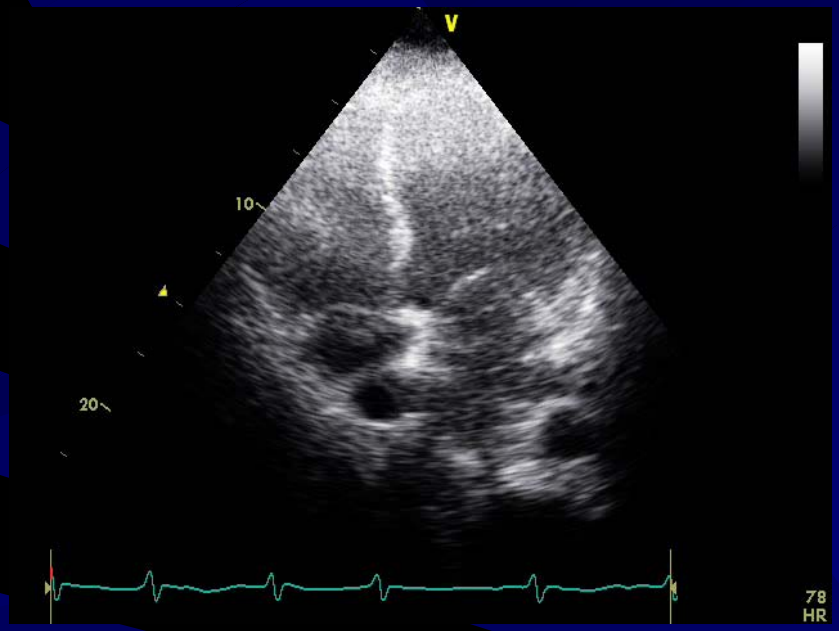
# Respiratory changes of aortic blood flow velocity in an animal model of hemorrhagic shock

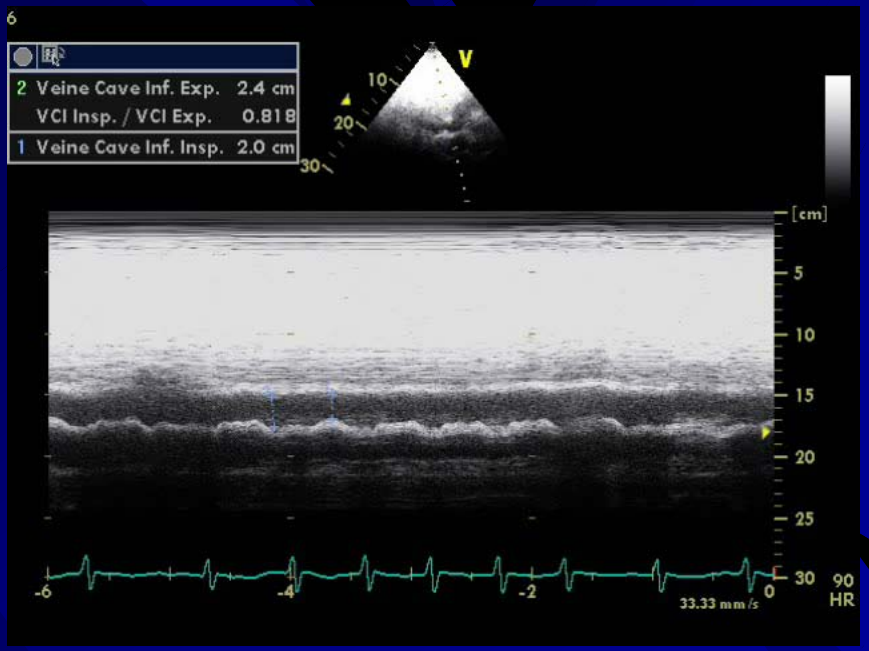


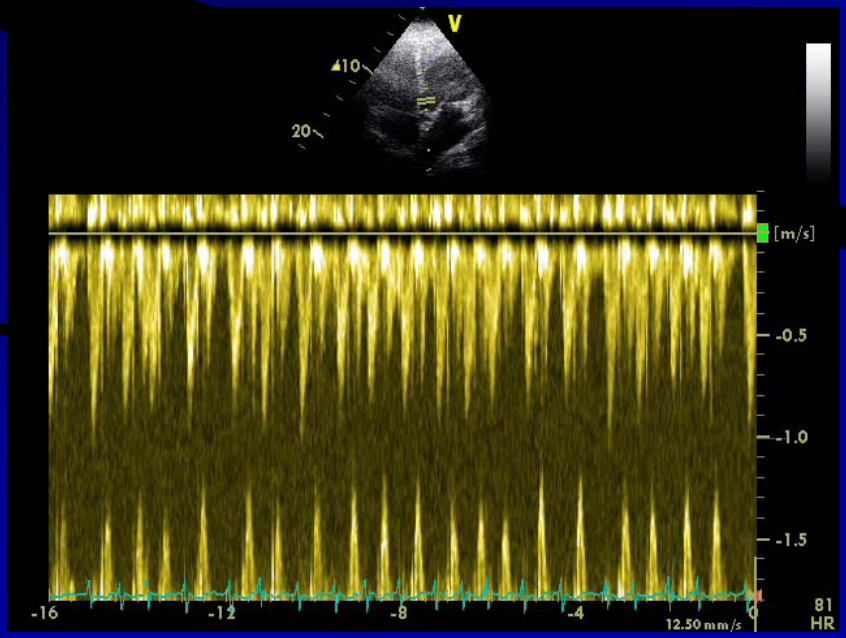
# Evaluation des besoins et suivi

- Variations respiratoires
  - VCI > 12% (18%)
  - VCS > 36 %
  - Vmax Ao > 12% (18%)
  - Vao Doppler oesophagien > 12%
- Lever jambe > 8-12%
- Débit cardiaque bas
- Tolérance PAPO




V
10
20
78
HR


6
2 Veine Cave Inf. Exp. 2.4 cm
VCI Insp. / VCI Exp. 0.818
1 Veine Cave Inf. Insp. 2.0 cm
V
10
20
30
[cm]
5
10
15
20
25
30
-6
-4
-2
0
33.33 mm/s
90
HR

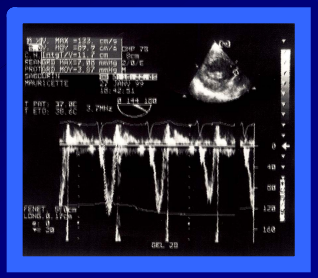

V
10
20
[m/s]
-0.5
-1.0
-1.5
-16
-12
-8
-4
0
12.50 mm/s
81
HR

Etat de choc d'allure septique

Cathéter radial et Echocardiographie

Variations respiratoires

QC, PAPO



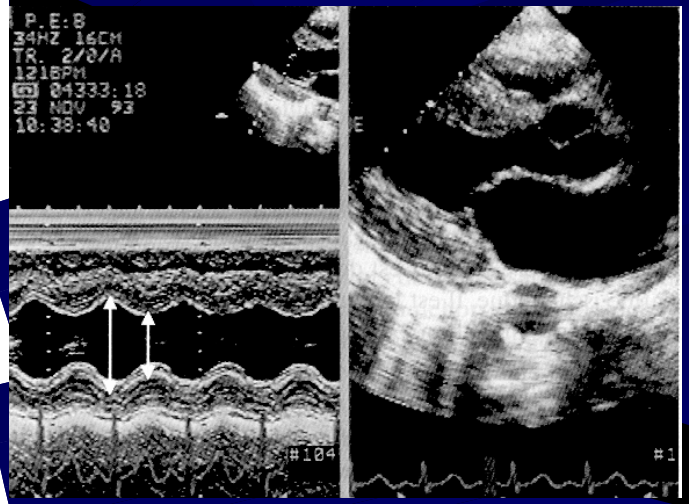
Oui : remplissage

Non : Pas remplissage

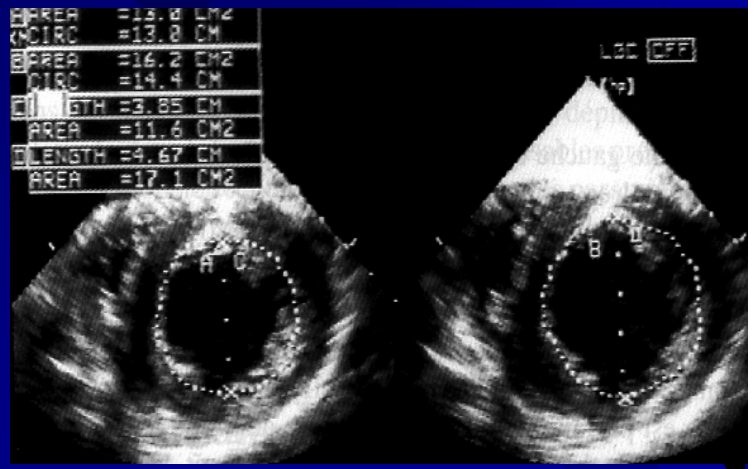
Evaluation de la fonction VG

# Systolic Function

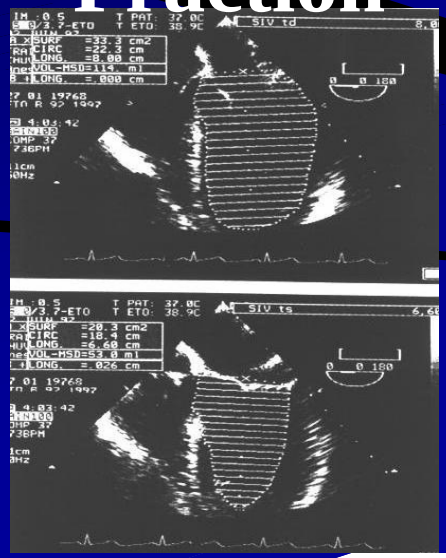
## Shortening Fraction



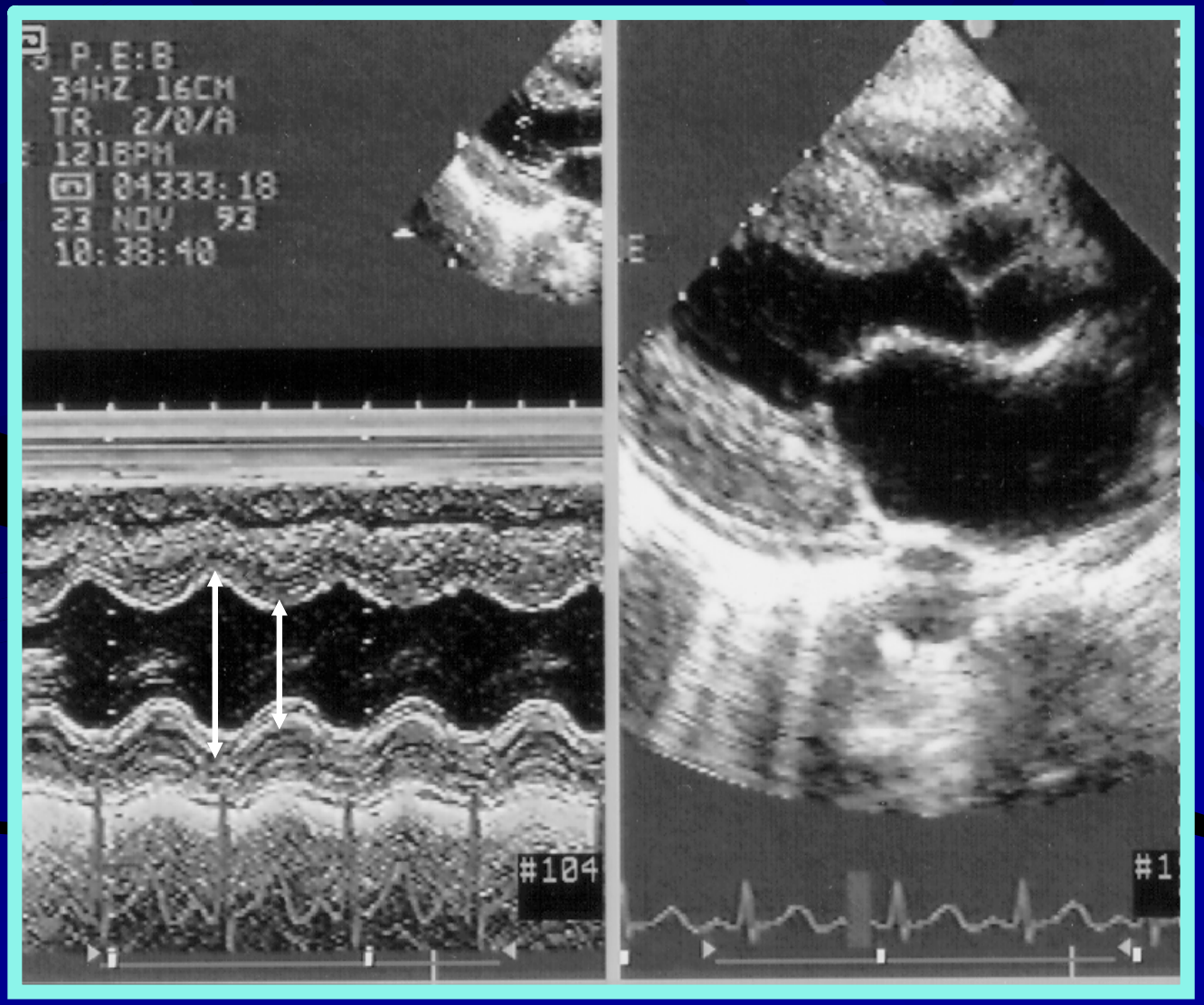
## Shortening Fraction of LV Area




## Ejection Fraction

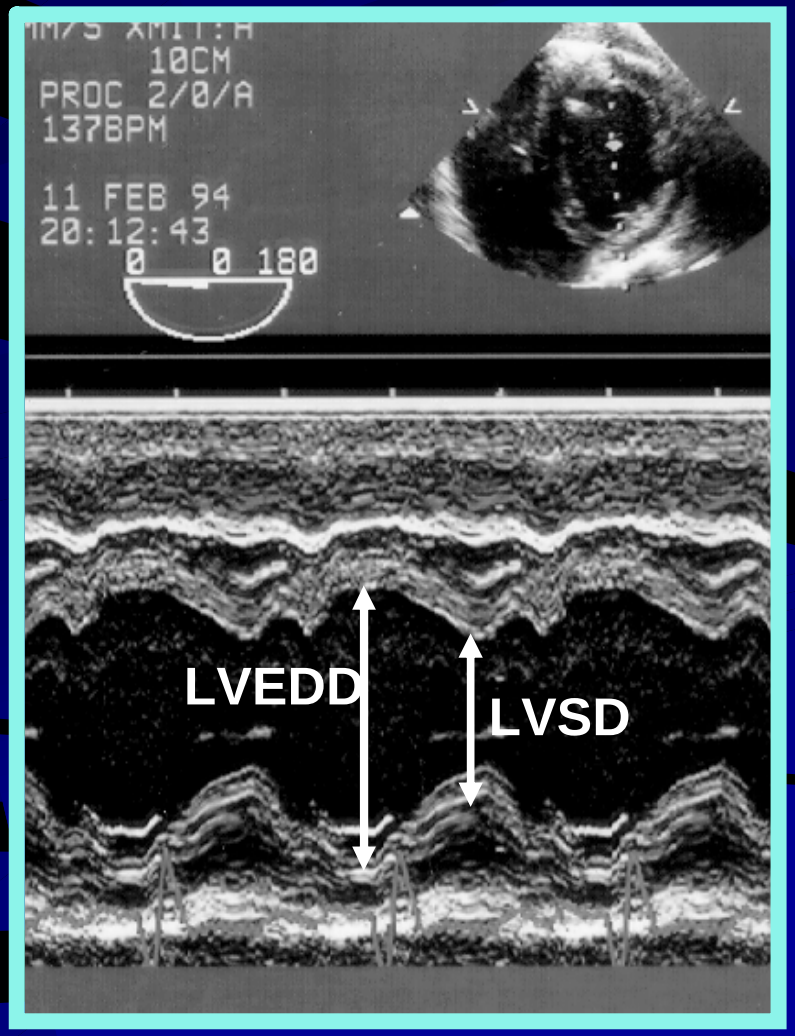


# Shortening Fraction




***Nle: 25 - 36 %***

# Velocity of circonferential fiber shortening

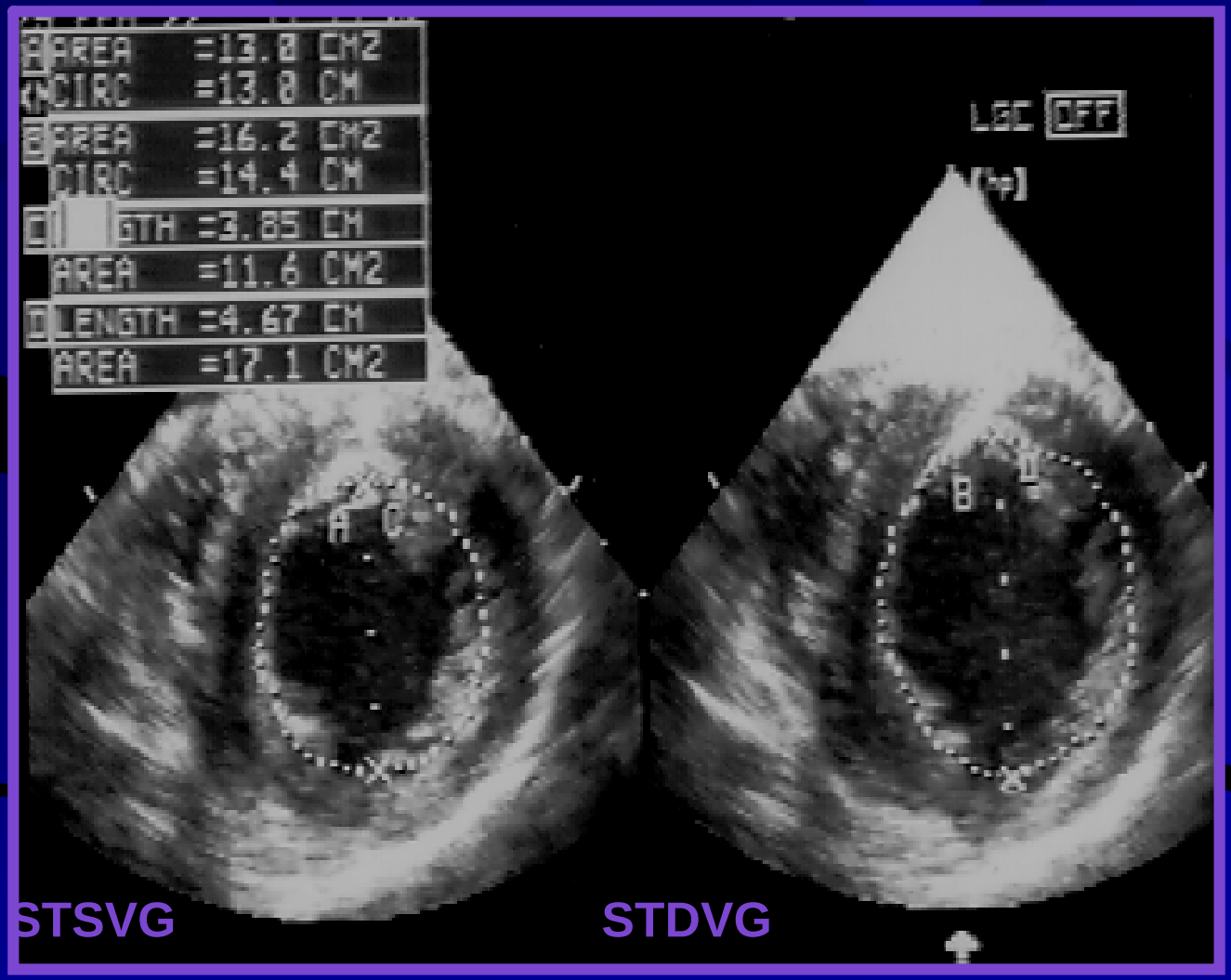



$$Vcf = SF / ET$$

$$Vcf\text{-}c = Vcf / V_{\overline{RR}}$$

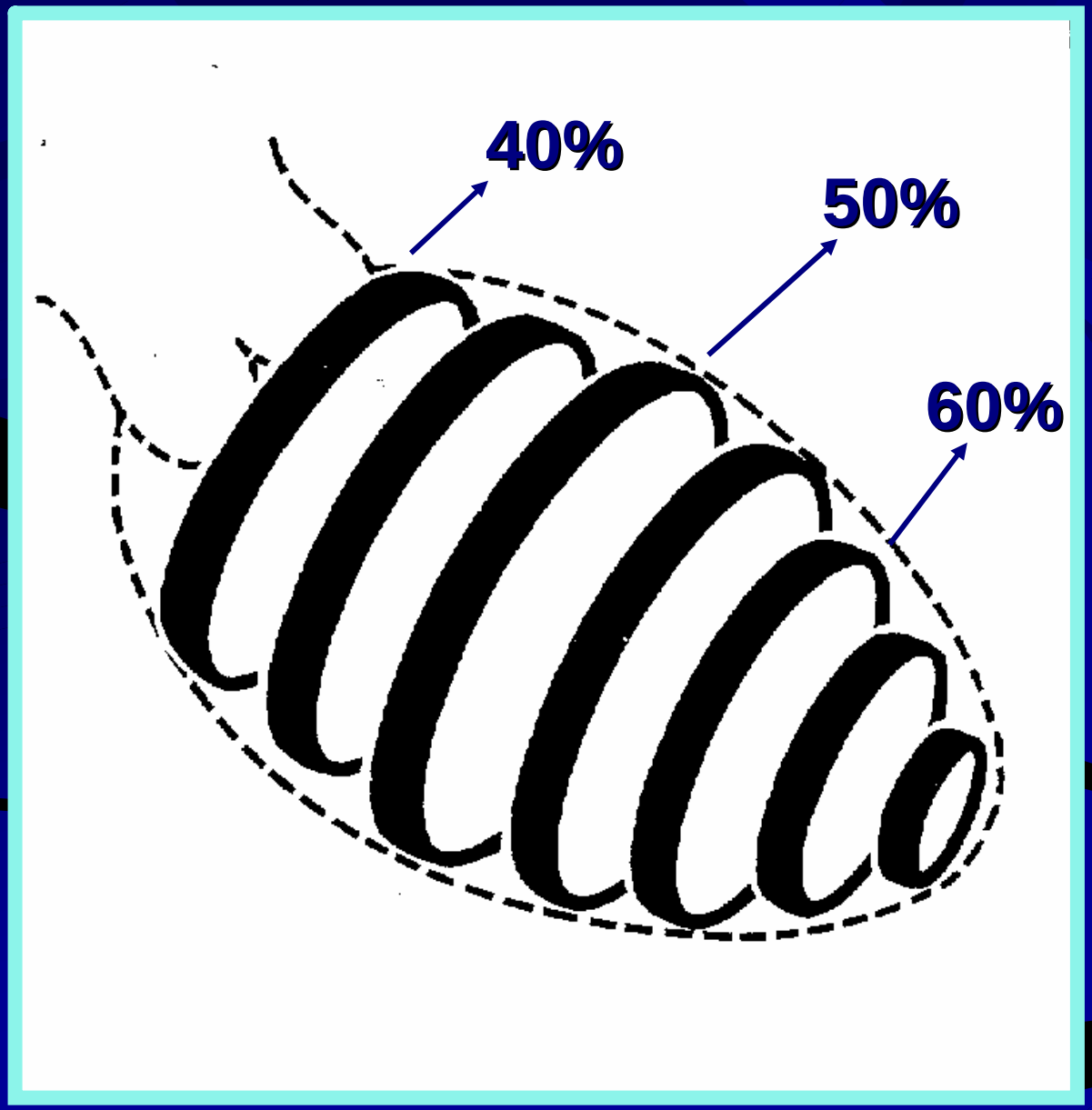
*SF = (LVEDD-LVSD) / LVEDD*

# Area Shortening Fraction

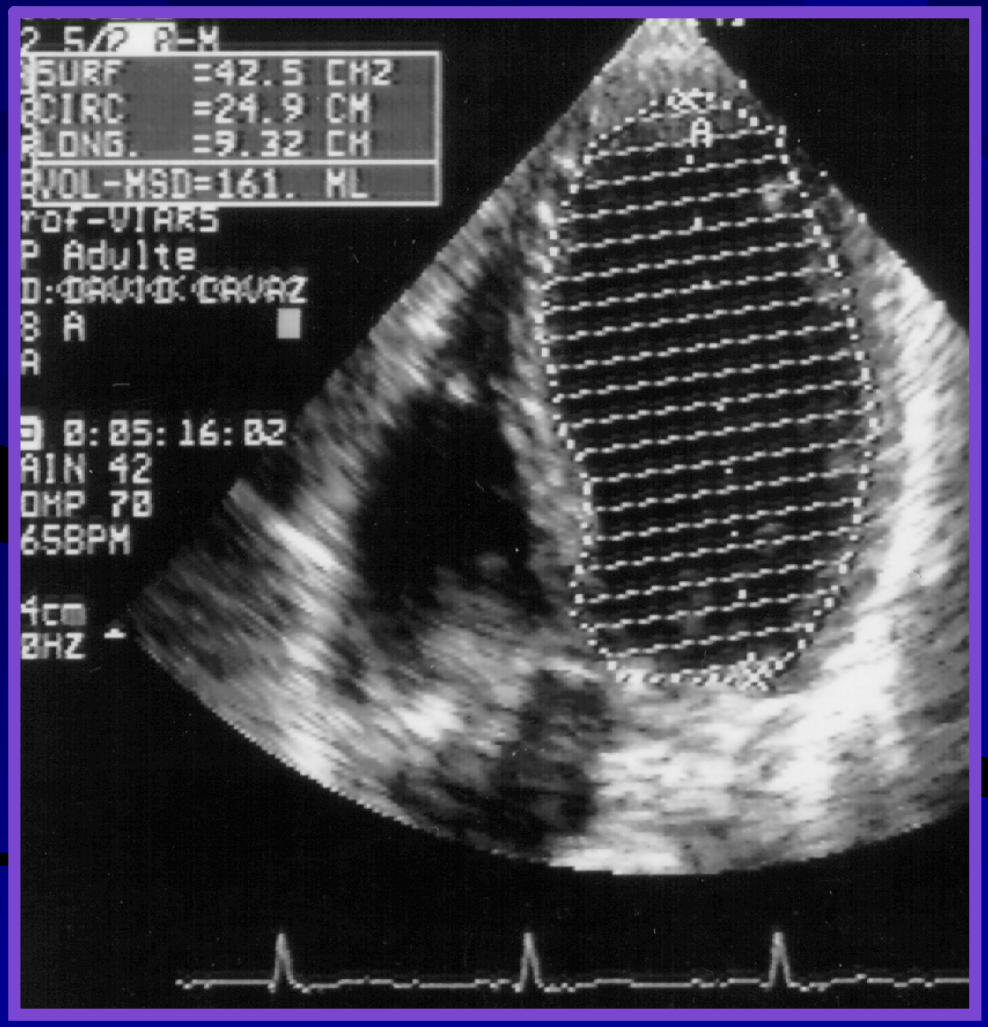



***Nle: 38 - 64 %***

# Area Shortening Fraction

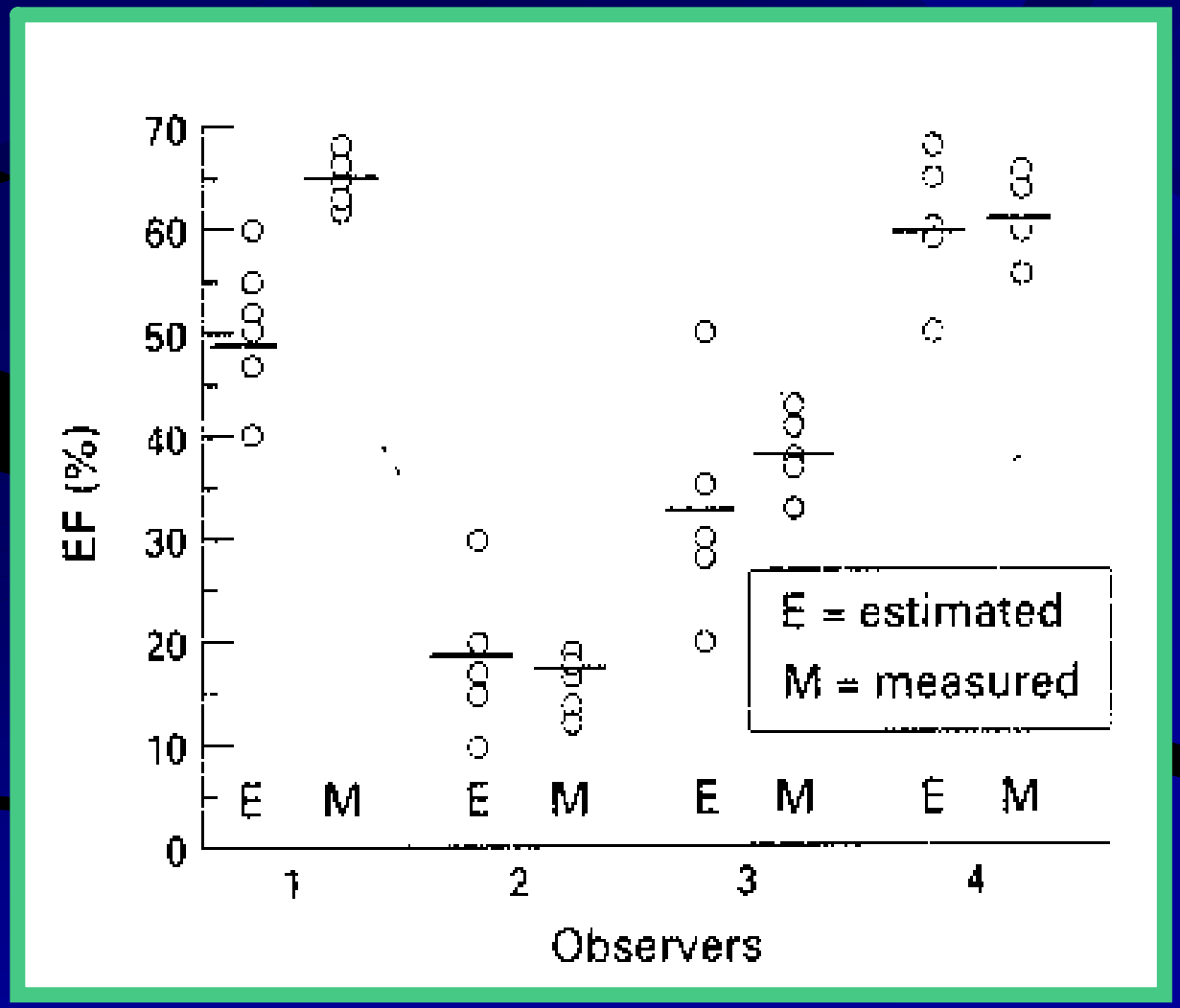


# Ejection Fraction




***Nle: 55 - 75 %***

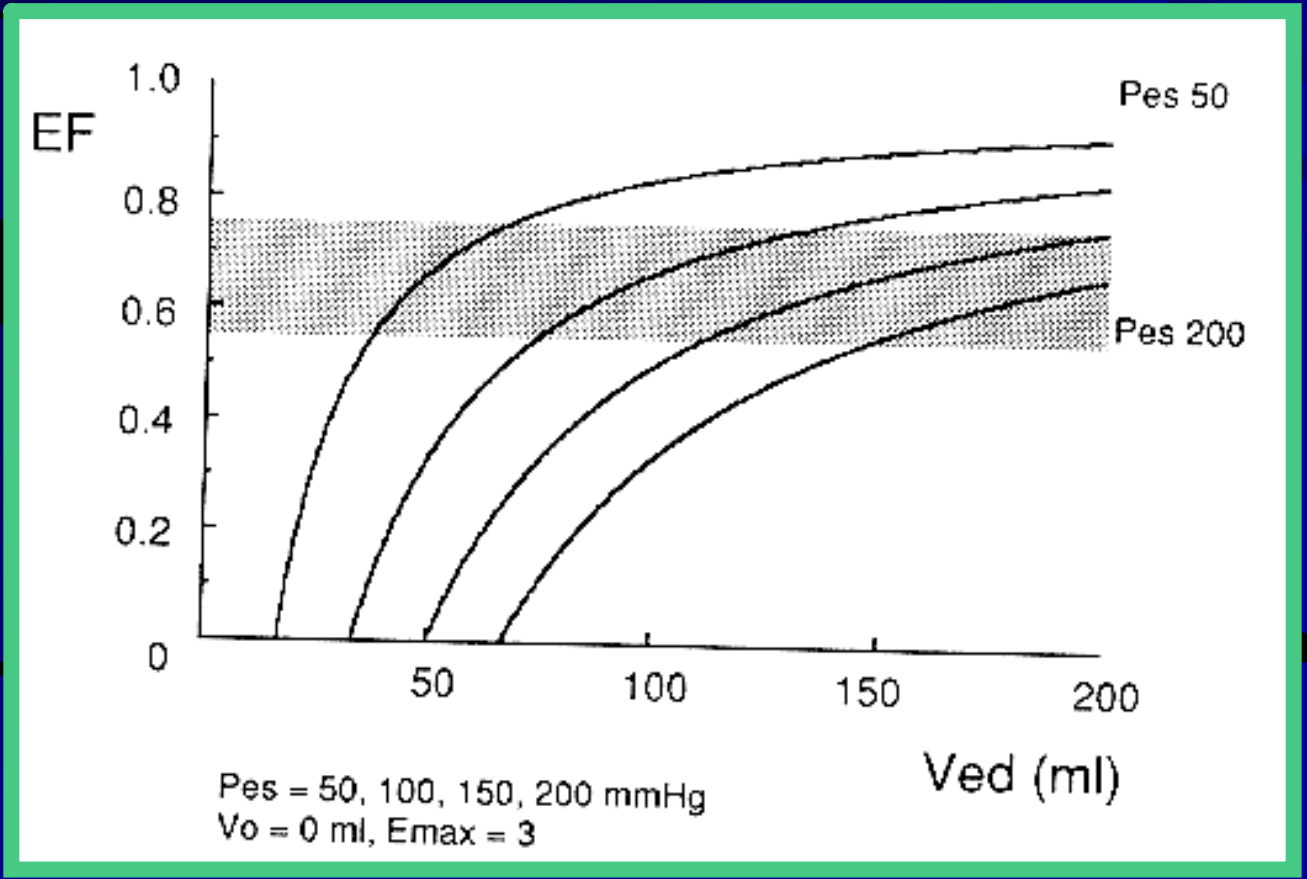
# Estimated and measured EF




*NB Shiller, Heart, 1996;75:17-26*

# Relationship between contractility (Emax), ejection fraction (EF), systolic pressure (Pes) and end-diastolic volume (Ved)

$$EF = 1 - (Pes / Ved)\ (1 / E_{max})$$




*Robotham J, anesthesiology, 1991;74:172-183*

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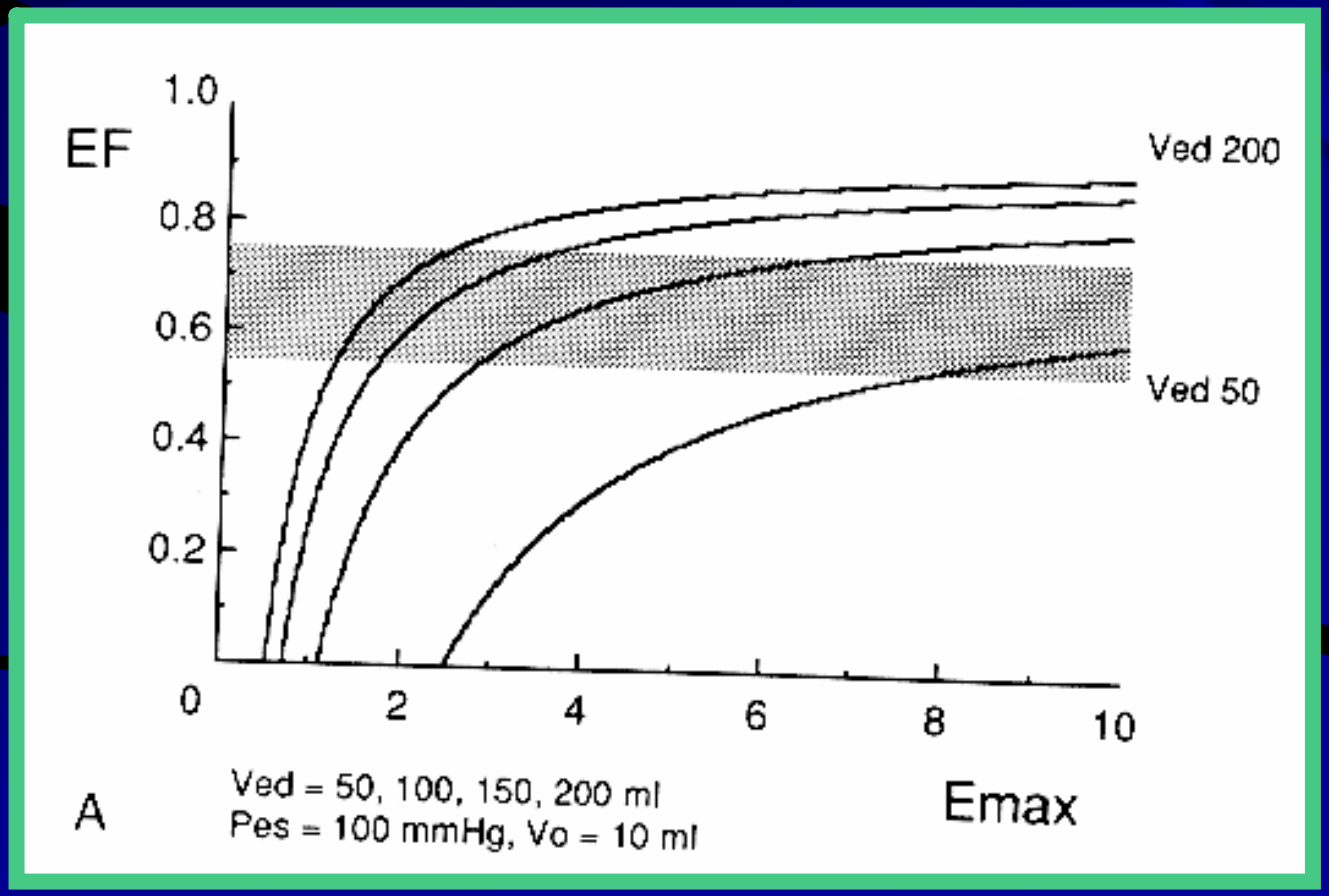


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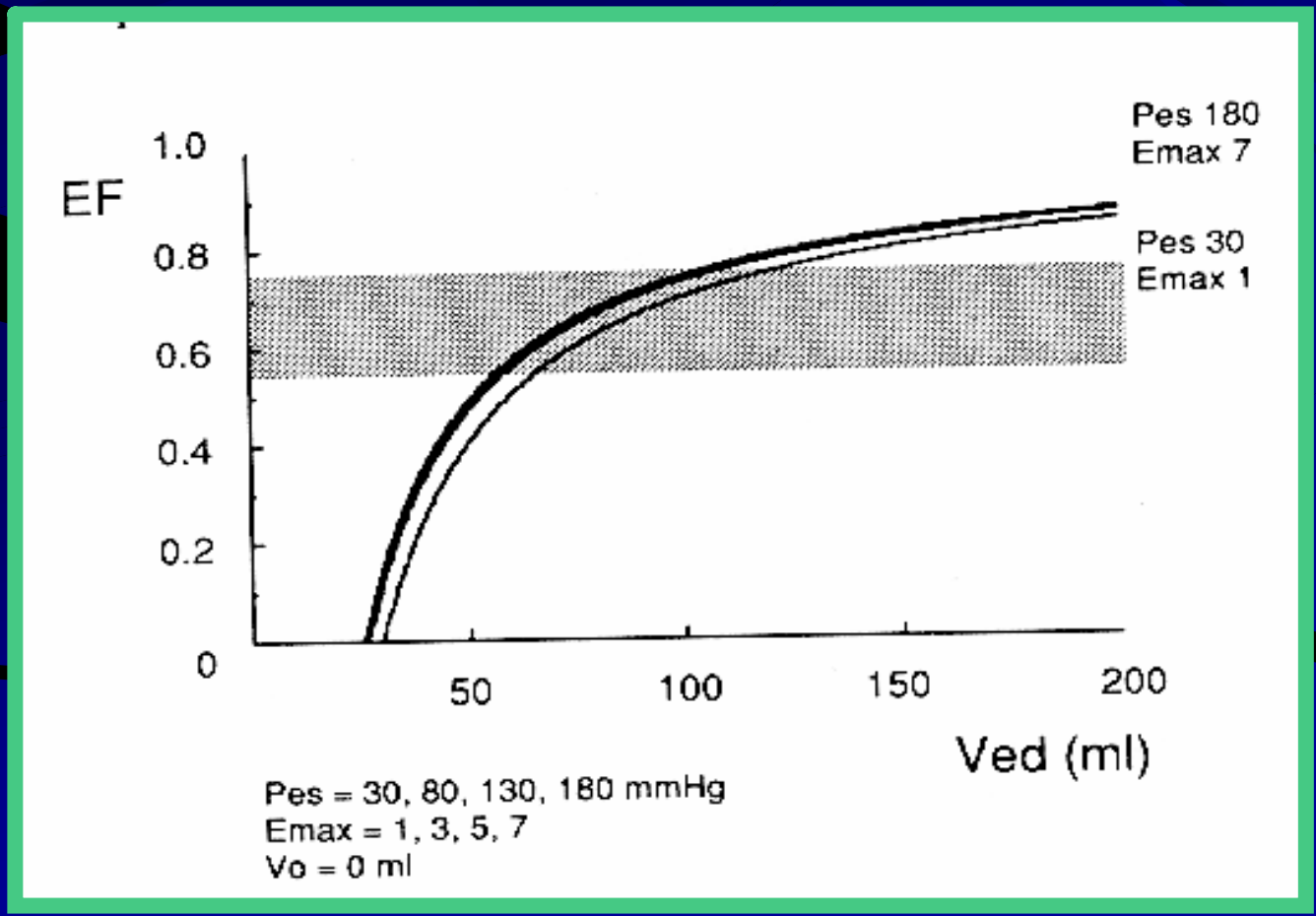
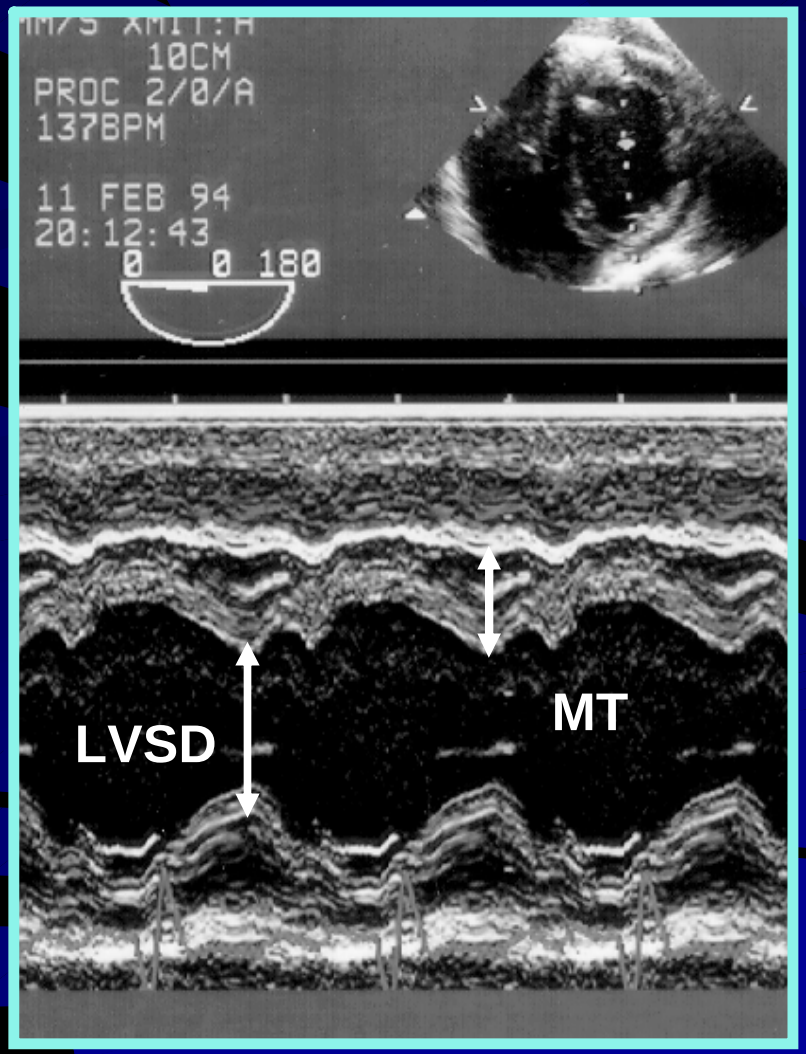



*Robotham J, anesthesiology, 1991;74:172-183*

# Systolic Stress




$$\frac{0{,}334 \cdot SAP \cdot LVSD}{MT \cdot (1 + MT / LVSD)}$$

*SAP = Systolic Arterial Pressure*

*LVSD = LV systolic diameter*

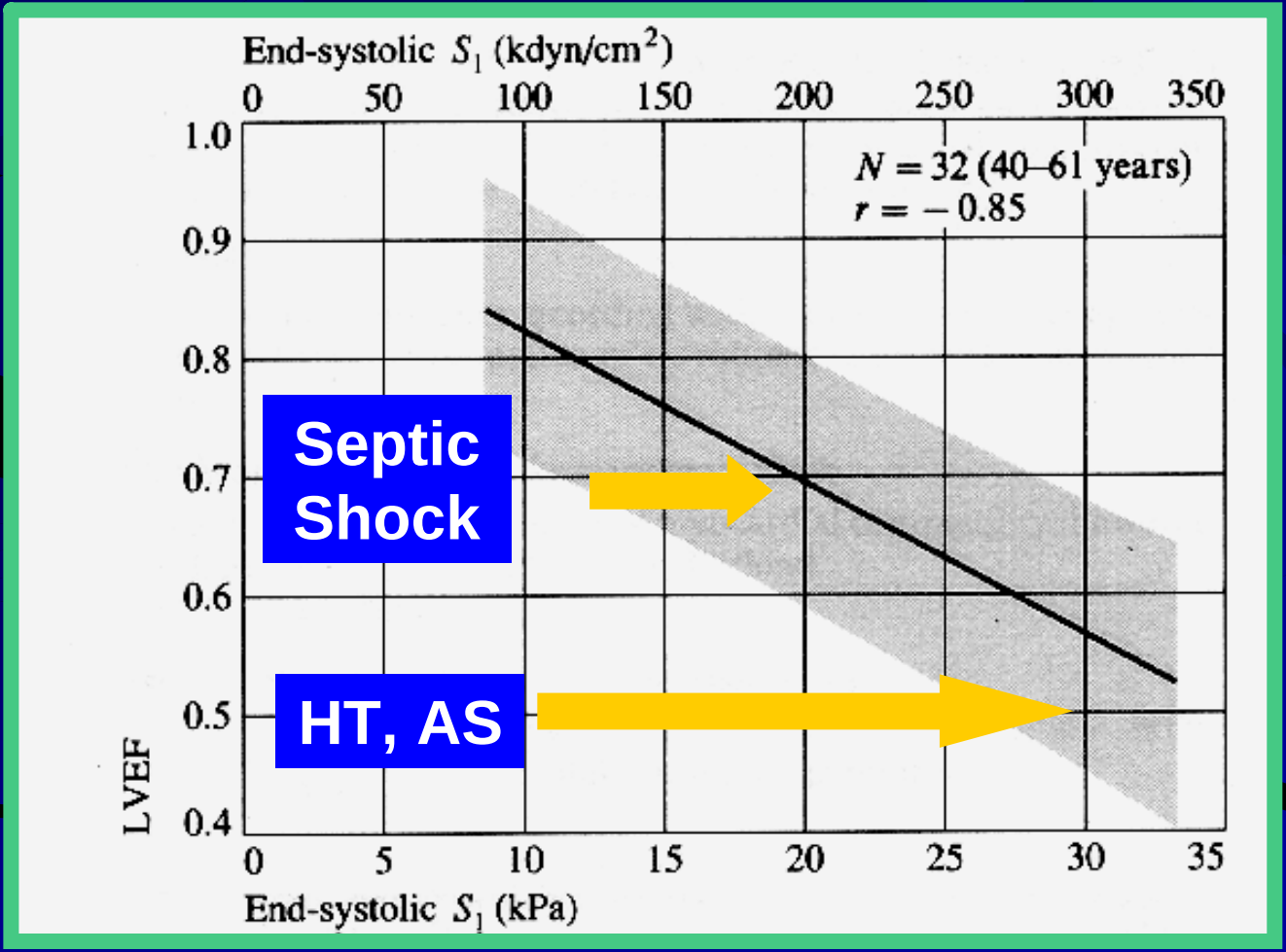
*MT = Myocardial thickening*

*O.334 = factor of correction from mmHg to g/cm2*

**Nles : 73 ± 21 Kdynes / cm2**

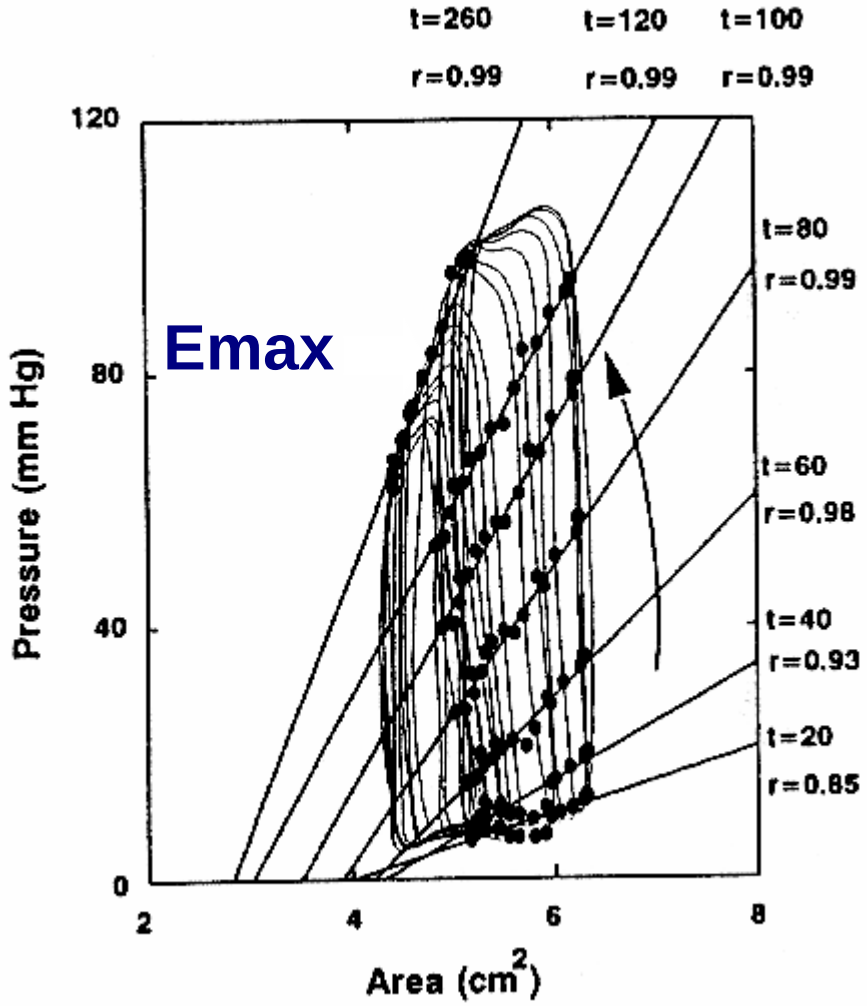
*Reischek N, Circulation, 1982;65:99-116*

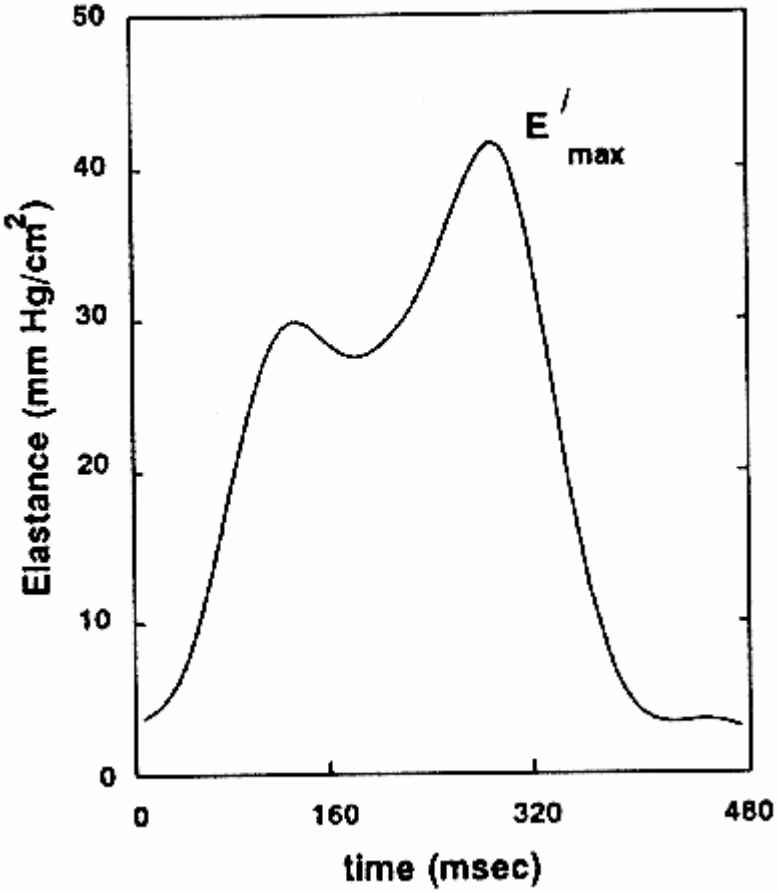
# EF-Systolic stress relationship



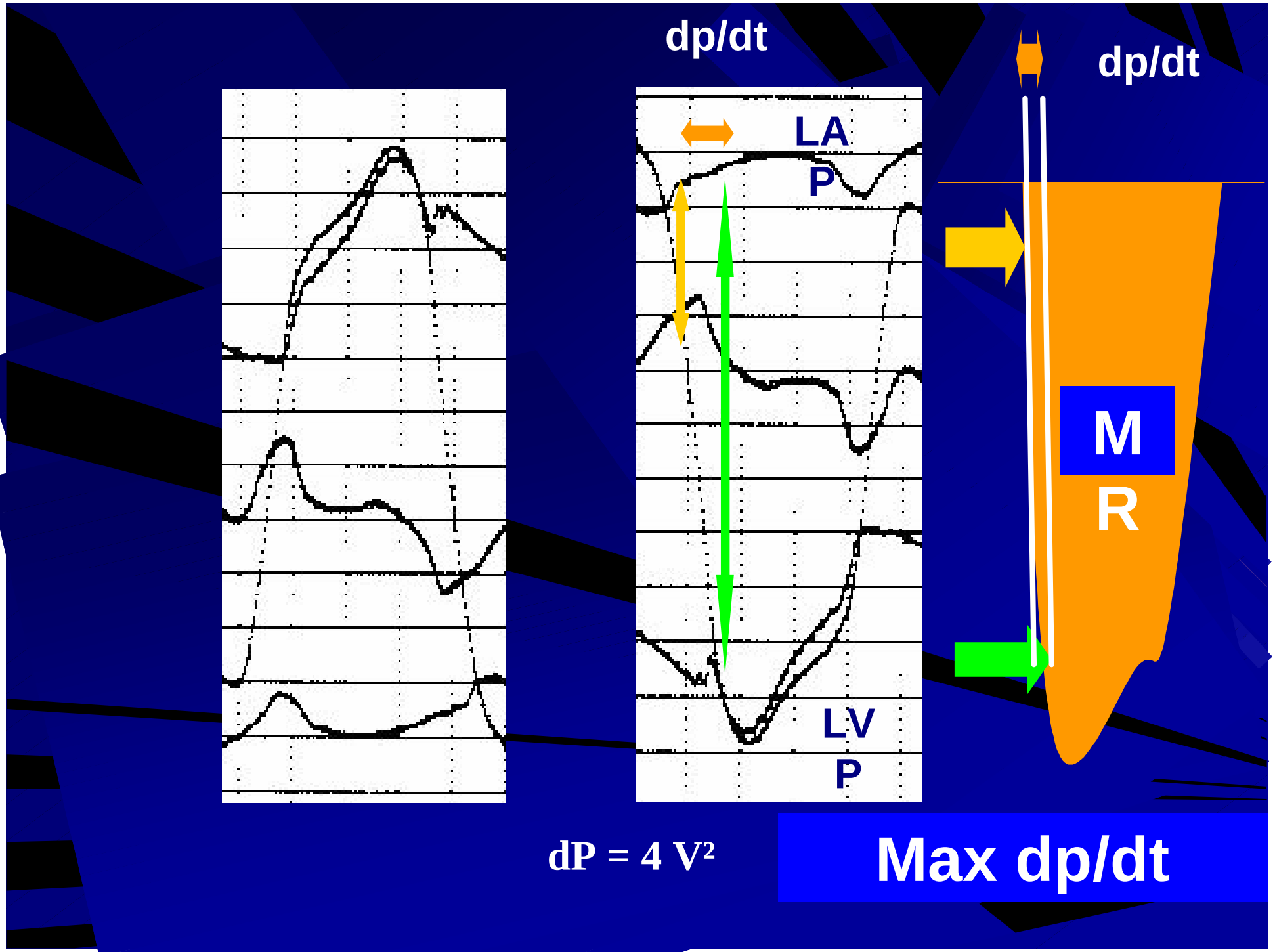

*Pouleur, Am J Cardiol, 1983;52:813-21*

# Emax = Maximal Elastance

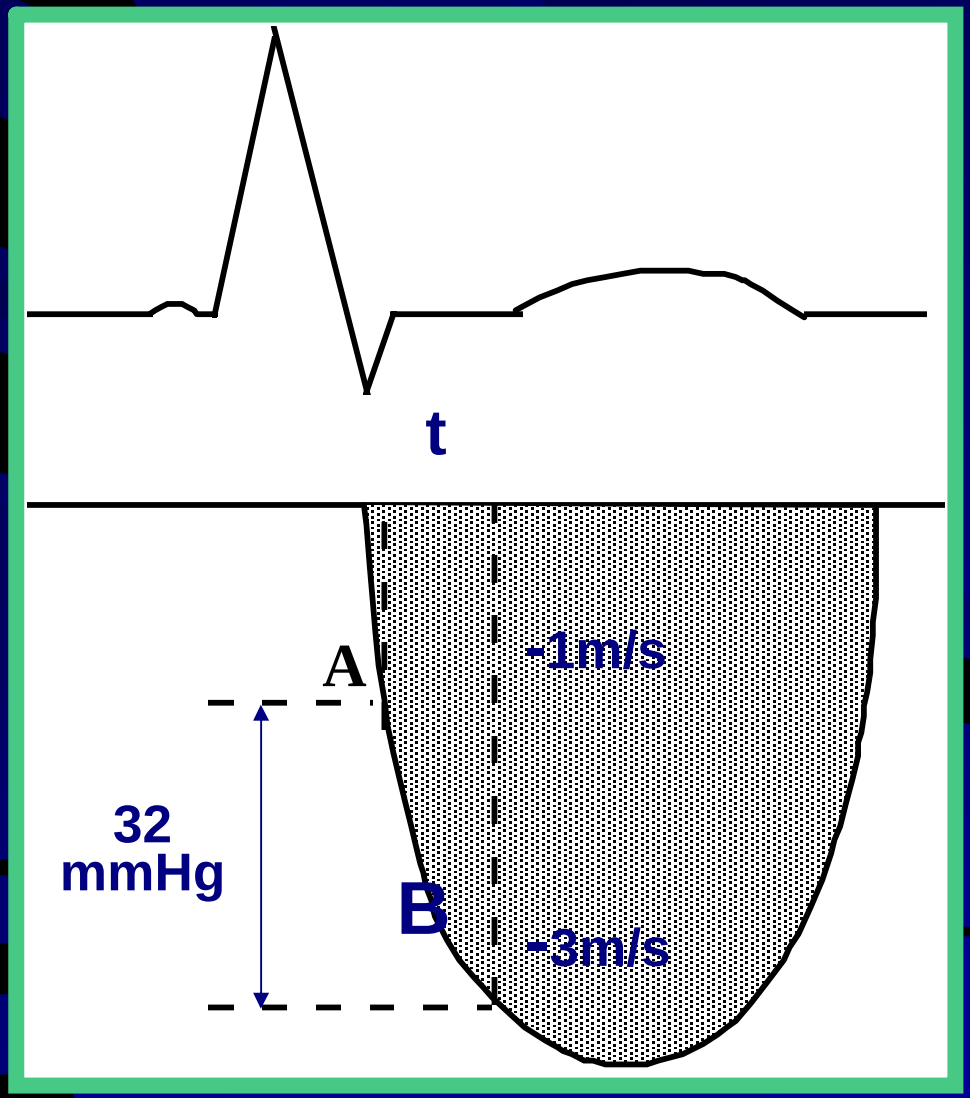



*GorscanIII J, Anesthesiology, 1994;81:553-62*


dp/dt
LA
P
LV
P
dp/dt
M
R
dP = 4 V²
Max dp/dt

# Rate of pressure rise (RPR)

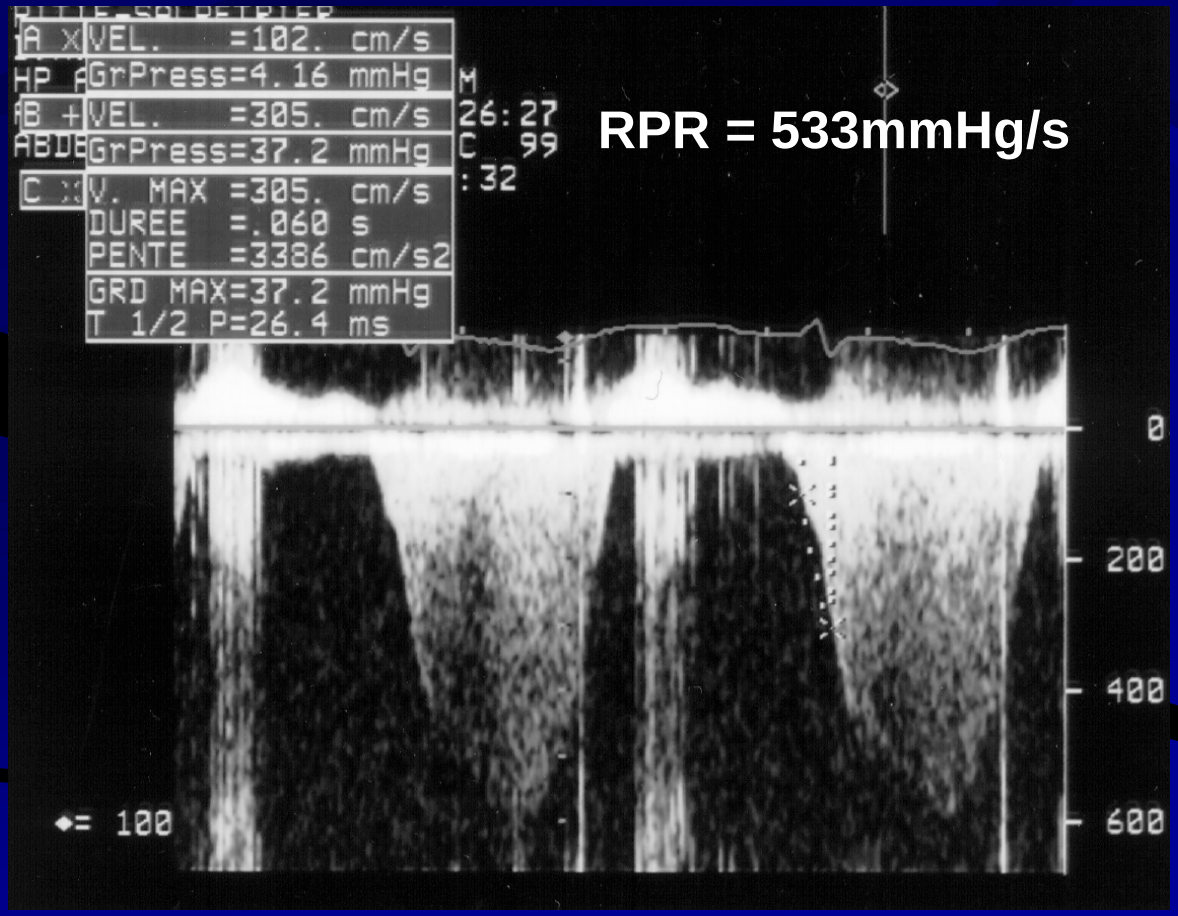



*Mathematical basis:*

*Bernouilli equation*

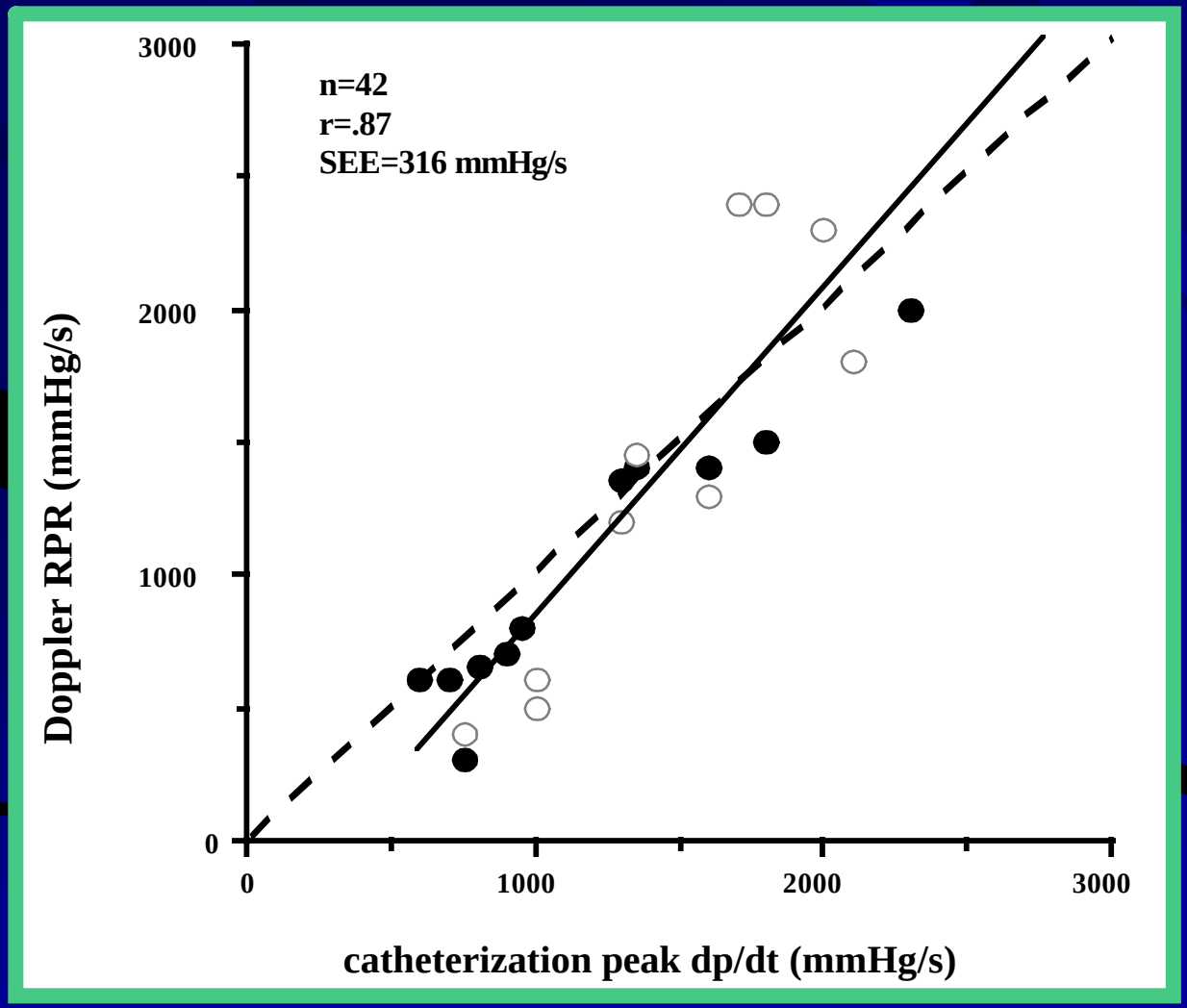
$$dP = 4V_A^2 - 4V_B^2$$

$$RPR = \frac{32\text{mmHg}}{t\ (\text{sec})}$$


VEL. =102. cm/s
GrPress=4.16 mmHg
VEL. =305. cm/s
GrPress=37.2 mmHg
V. MAX =305. cm/s
DUREE =.060 s
PENTE =3386 cm/s2
GRD MAX=37.2 mmHg
T 1/2 P=26.4 ms
26:27
99
:32
RPR = 533mmHg/s
0
200
400
600
100

# Estimation of LV dP/dt with CW Doppler

## Validation at cardiac catheterization




*Bargiggia, Circulation, 1989*

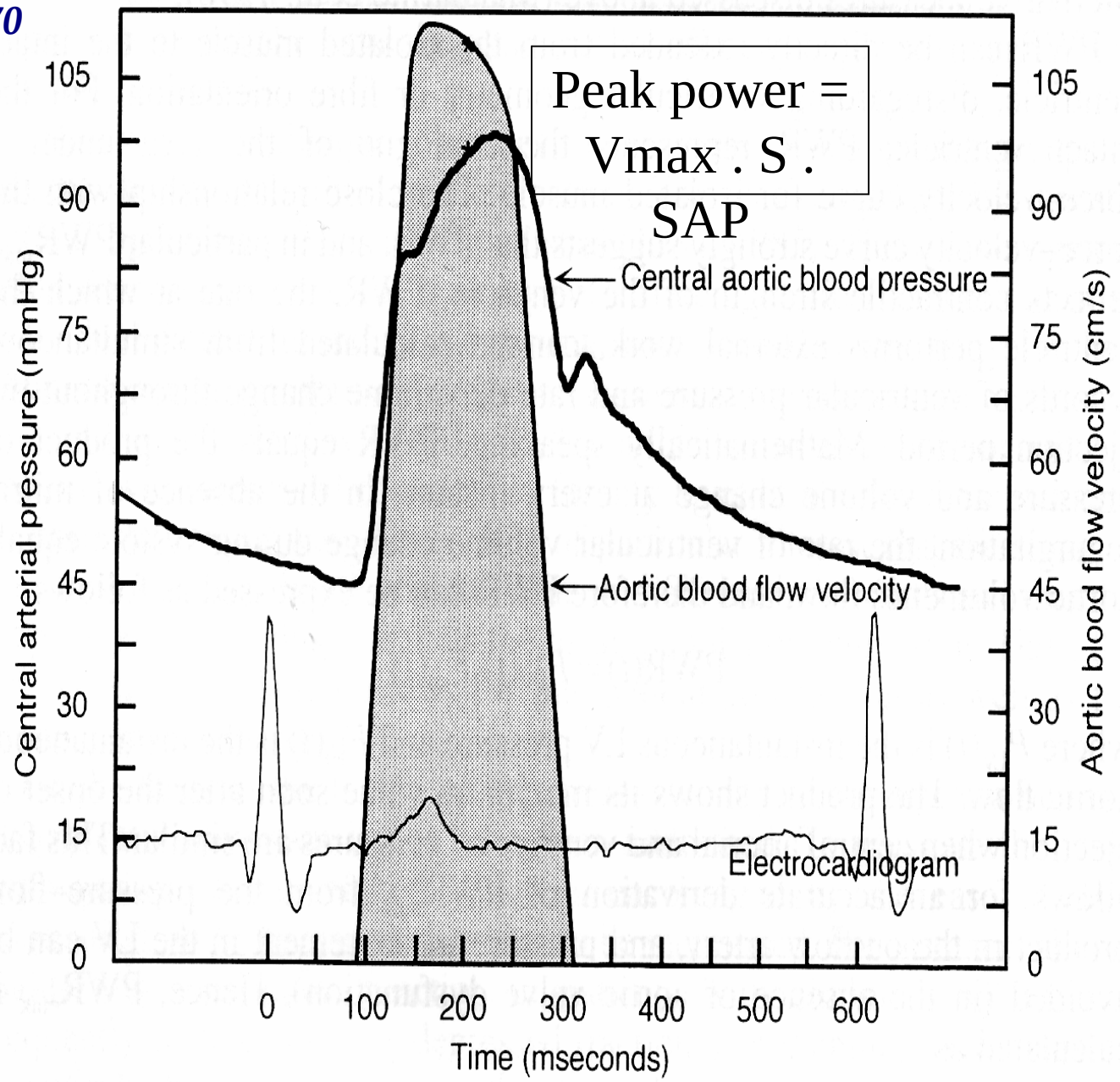
# Peak power

**Power = Flow . Pressure**

**(Watts) (ml / s) (mmHg)**

*Mandarino WA, J Am Coll Cardiol, 1998;31:861-8*
*Armstrong GP, Heart, 1999,;82:357-64*

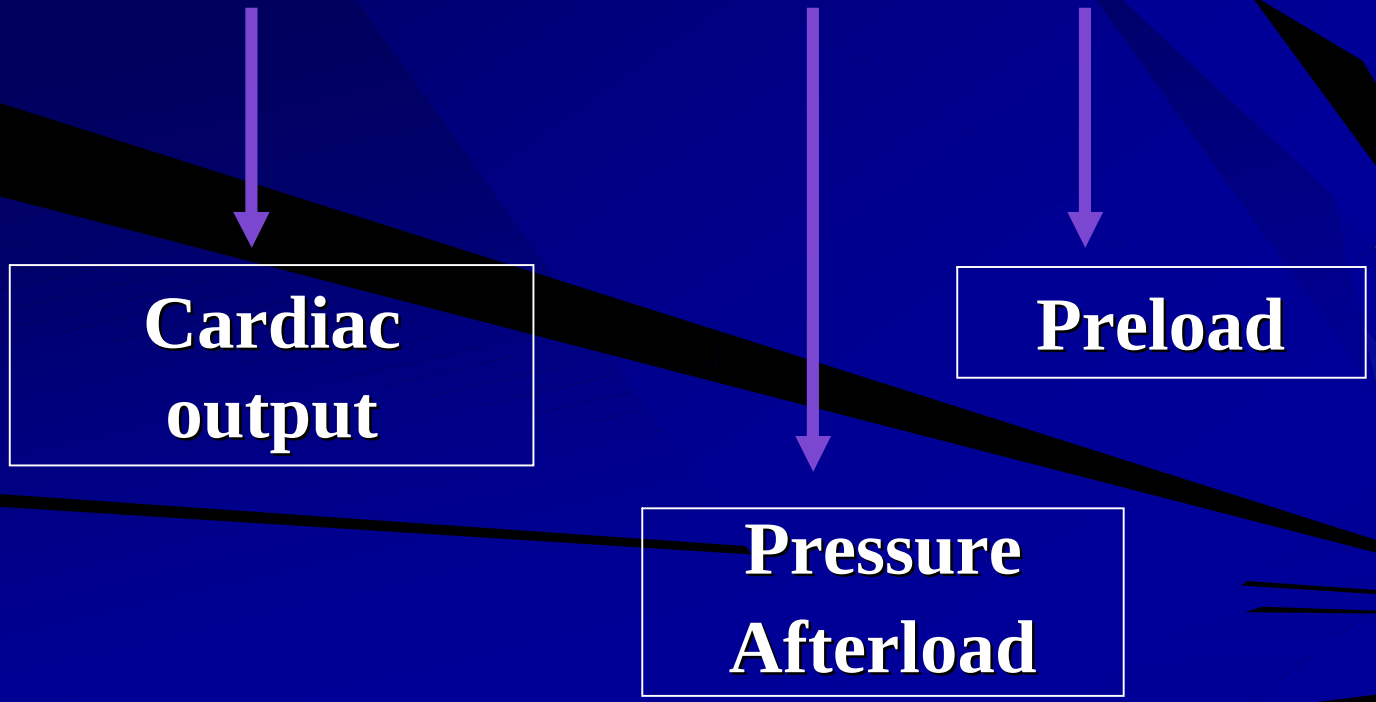
*Schmidt C, Anesthesio, 1999;91:58-70*



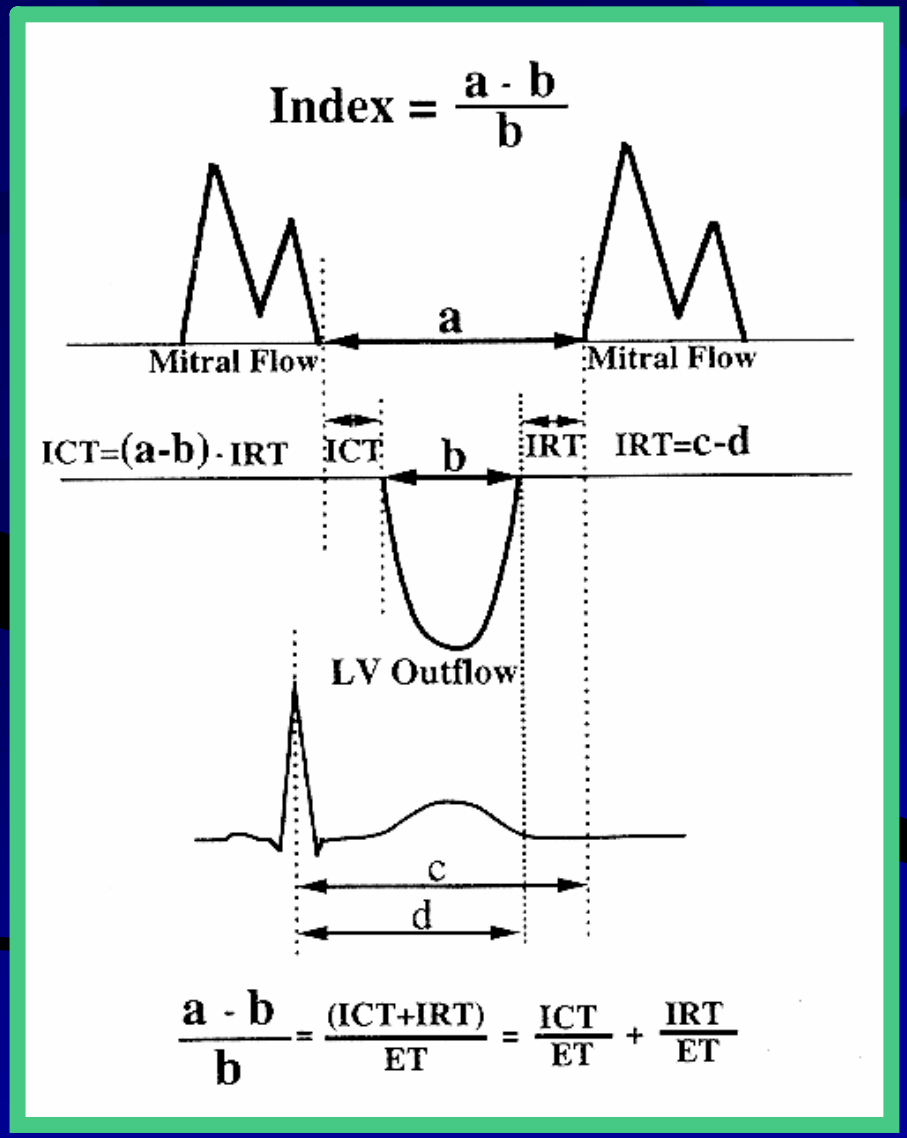
# Preload adjusted maximal power

**Preload adjusted maximal power ($mW/cm^4$)**

**= (instantaneous maximal flow . SAP ) / $EDA^2$**



# Intervalles isovolumétriques

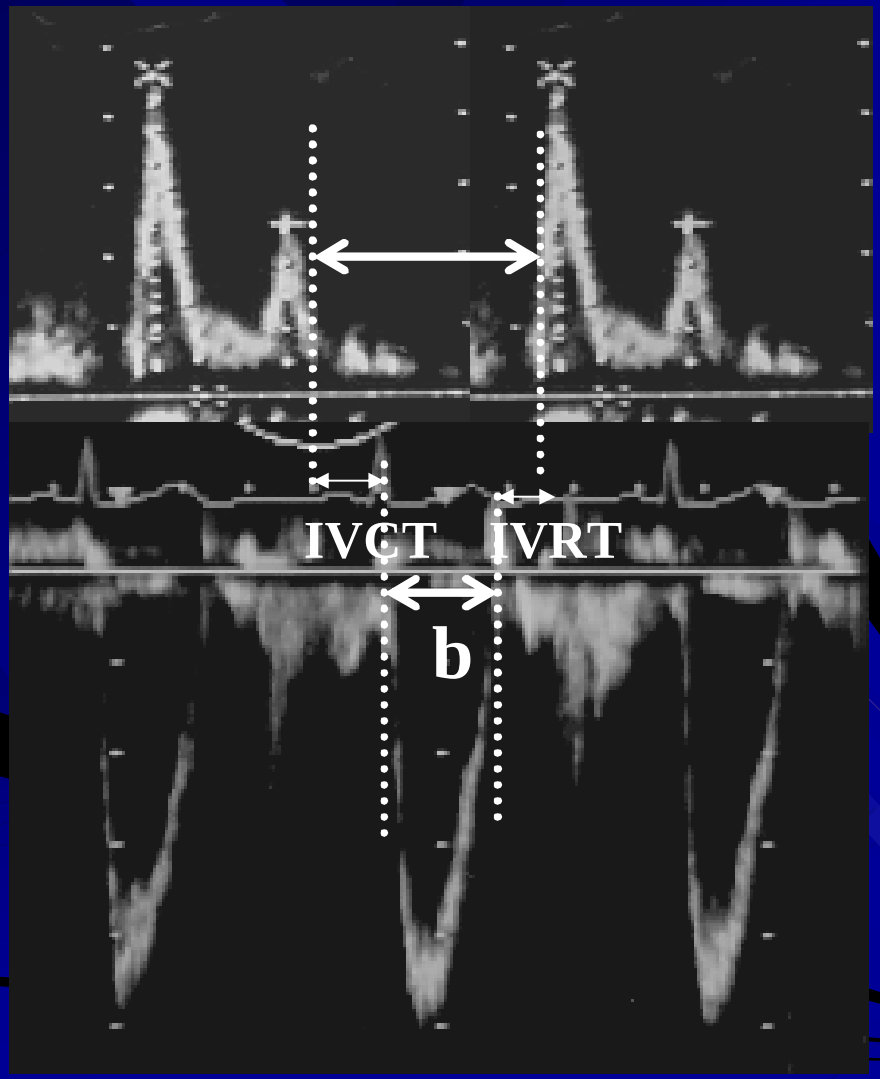



*Tei C, J Am soc Echo, 1997;10:169-78*

**Isovolumic contraction time (IVCT)**

**Isovolumic relaxation time (IVRT)**

**MI: (IVCT+ IVRT) / ET**

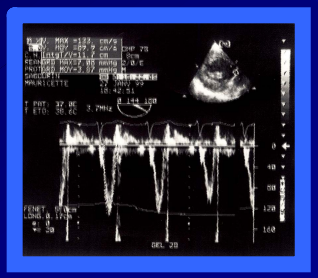



*Tei C, J Am soc Echo, 1997;10:169-78*

Etat de choc d'allure septique

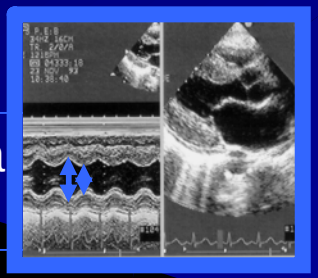
Cathéter radial et Echocardiographie

Variations respiratoires



Oui : remplissage

Non : remplissage



Evaluation de la fonction VG

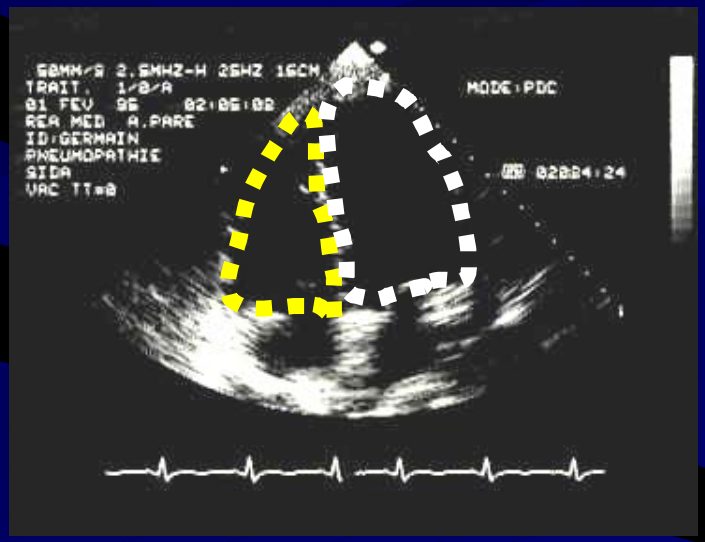
FE<40%

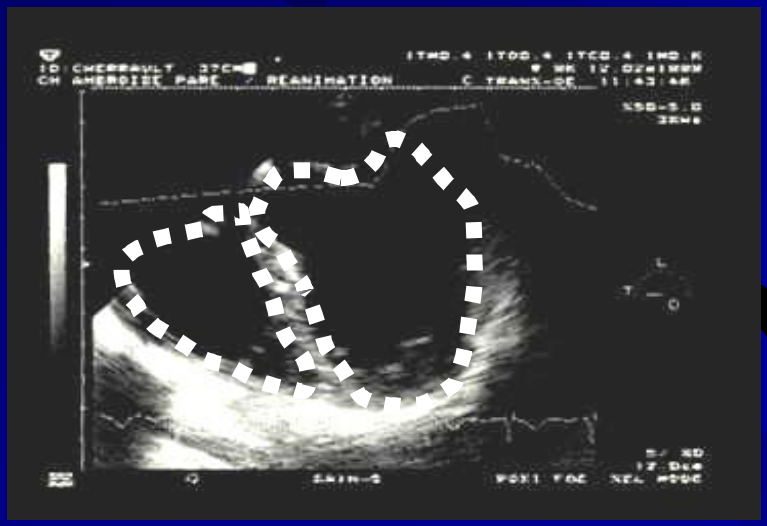
Oui : Dobutamine

Non : NA

Evaluation de la fonction VD : CPA

# DILATATION VD



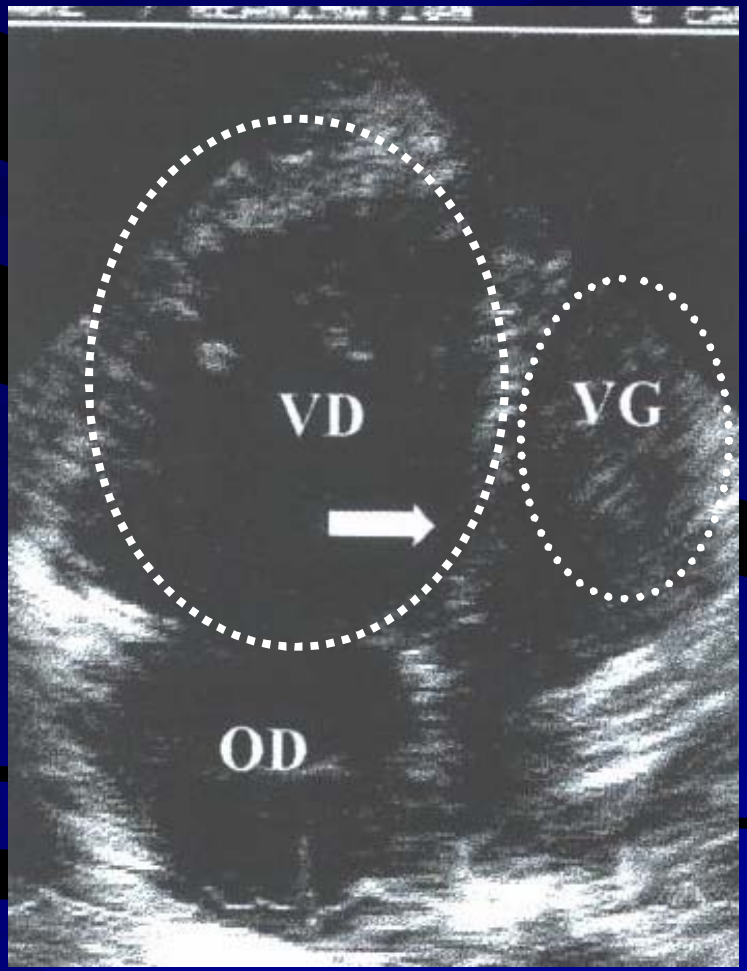
Pas de dilatation: STDVD/STDVG < 0.6

Dilatation modérée: STDVD/STDVG  0.6 - 1

Dilatation majeure: STDVD/STDVG > 1

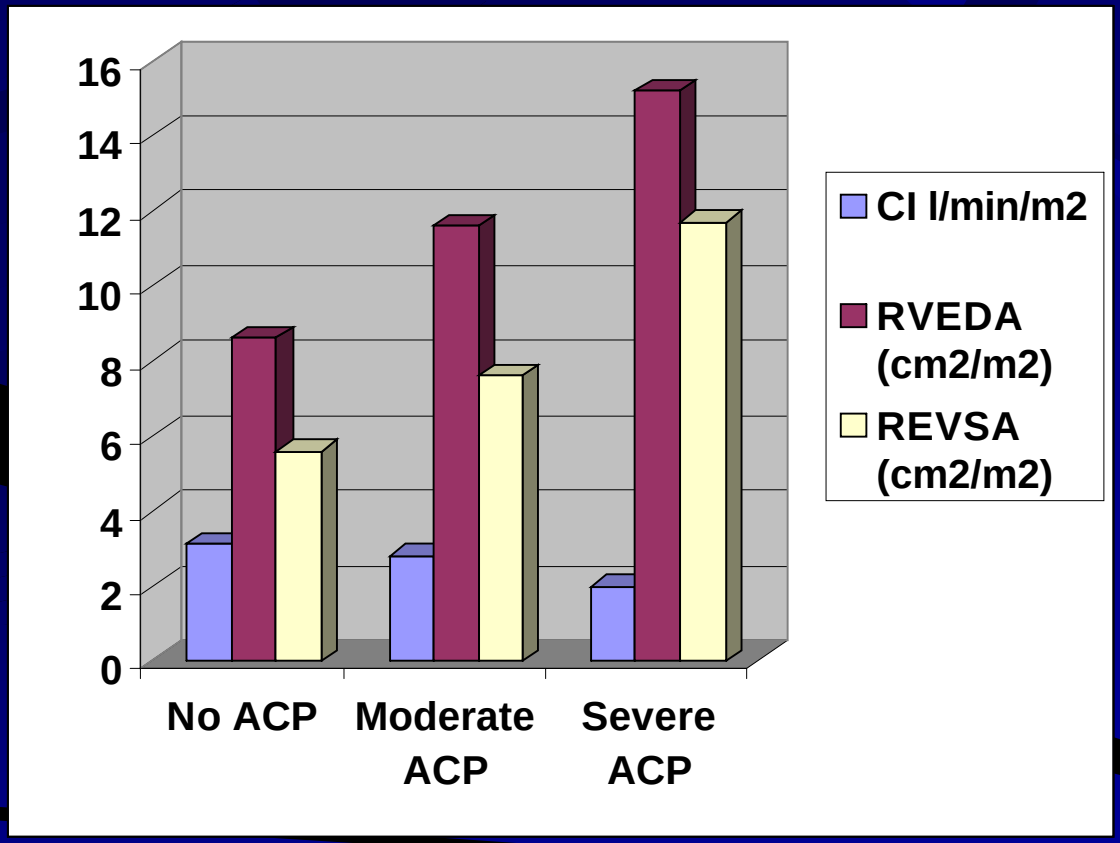
Jardin Chest 1997

# ARDS Cardiac Complication :



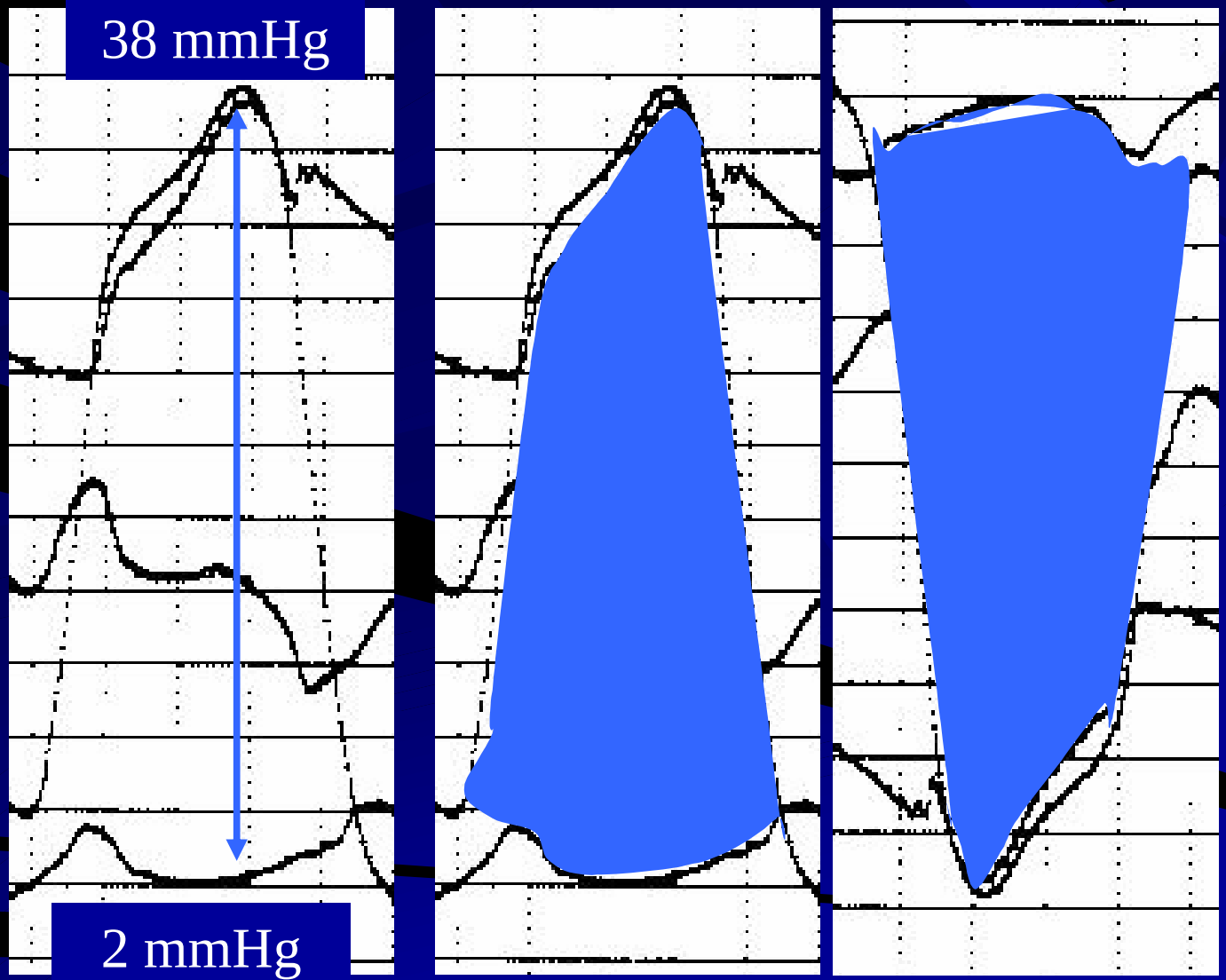

## Acute Cor Pulmonale

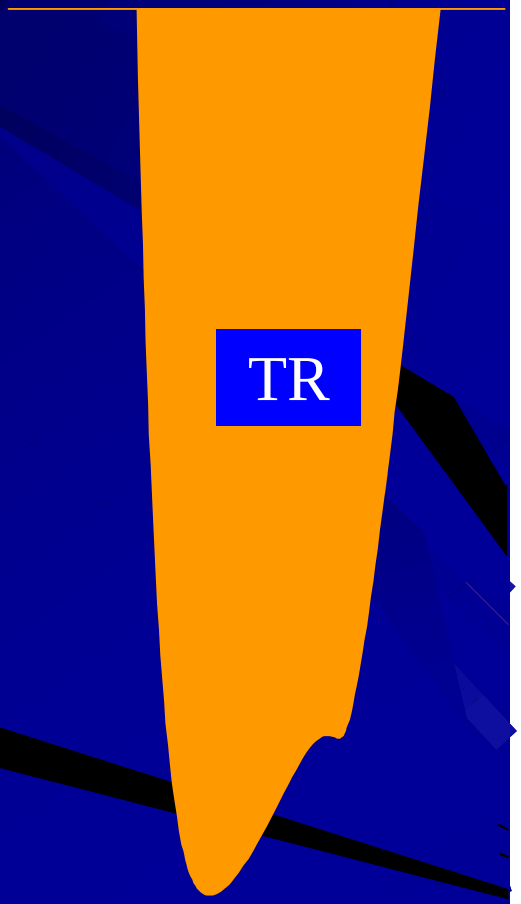
- Large RV
  - RVEDA/LVEDA:<0.6 = Normal
  - RVEDA/LVEDA: 0.6-1 = Moderate ACP
  - RVEDA/LVEDA:>1 = Severe ACP
- Small LV with impaired relaxation
- Septal dyskinesia
- PAPH




Vieillard-Baron A Am J Resp Crit Care Med 2002;166:1310-19

Pression arterielle pulmonaire



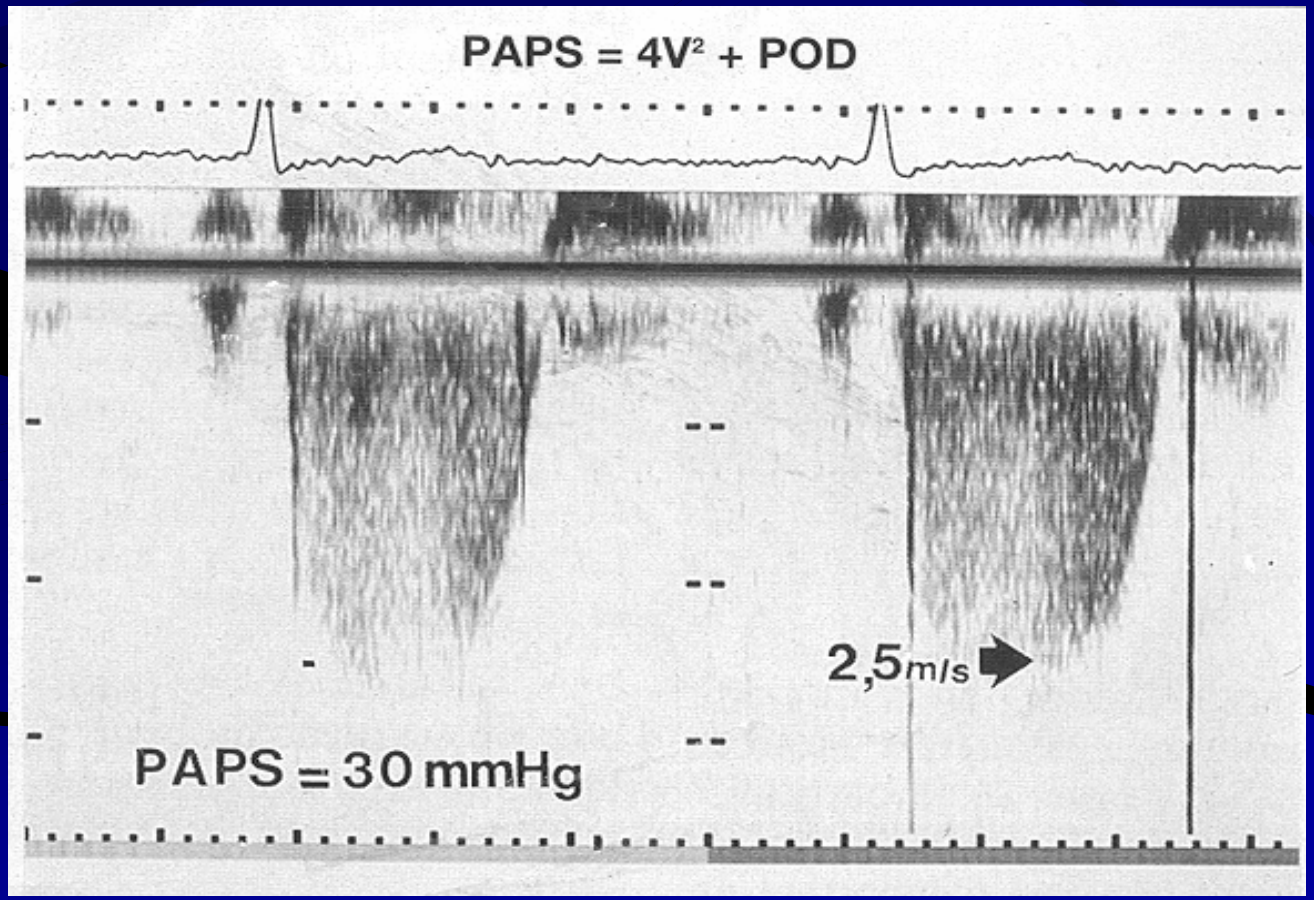



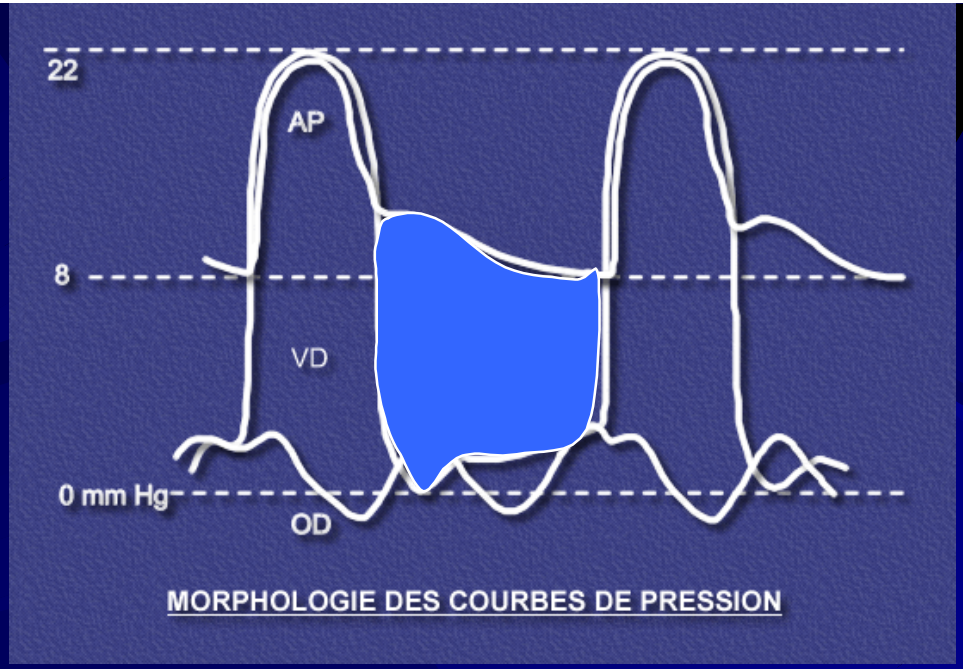

**Gradient** = 36 mmHg

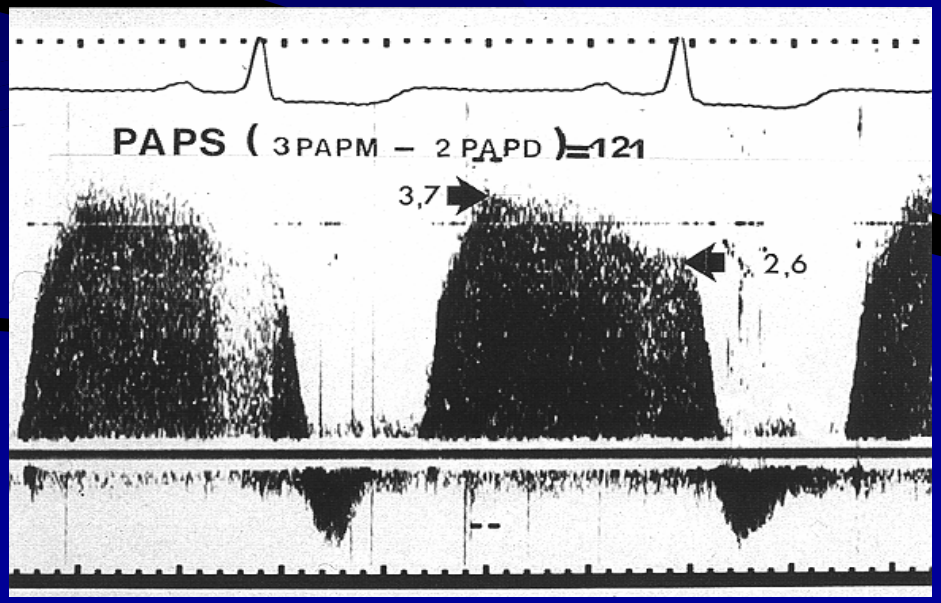
**dP = 4 V²**

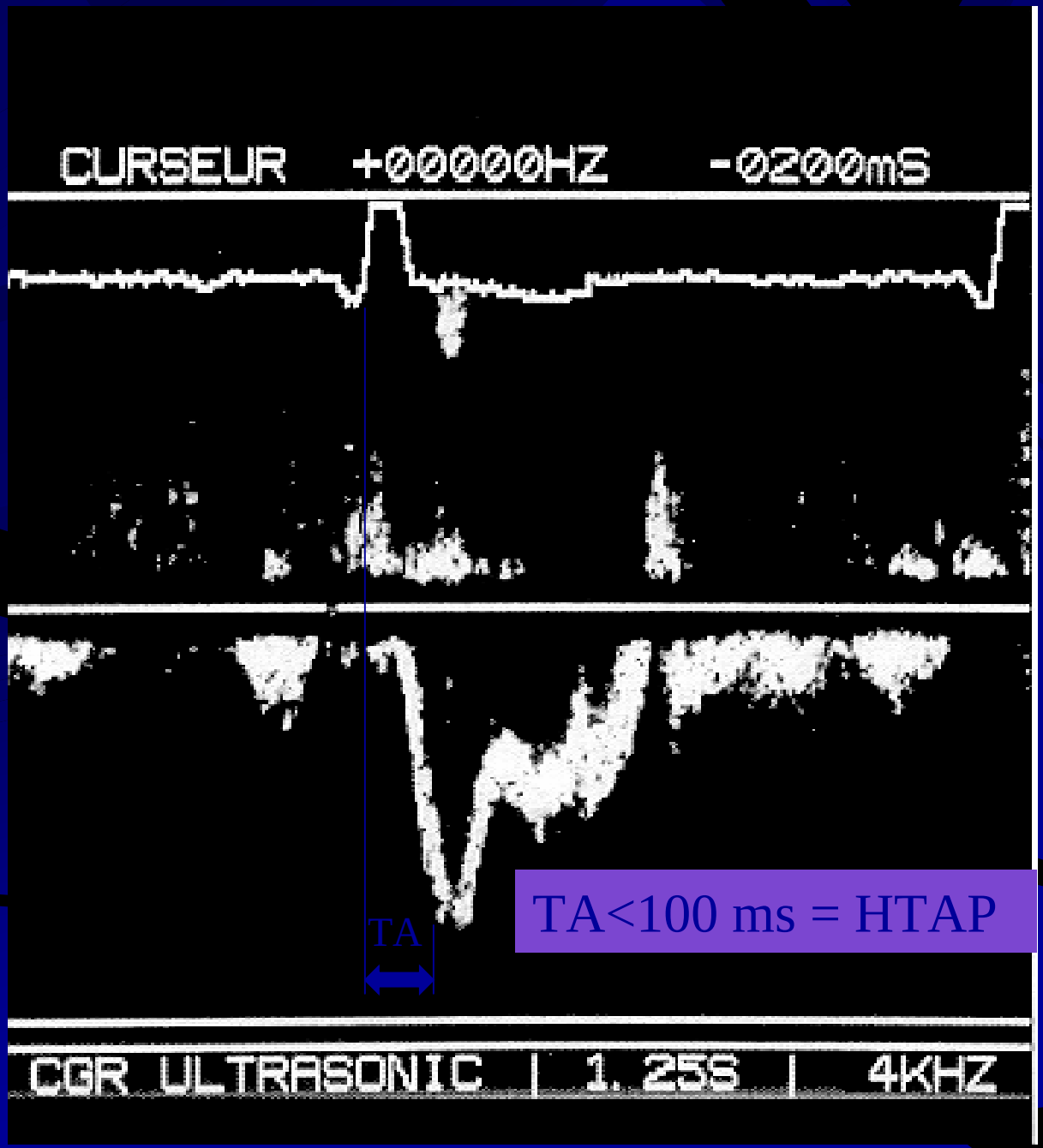
**Velocity**= 3 m/s

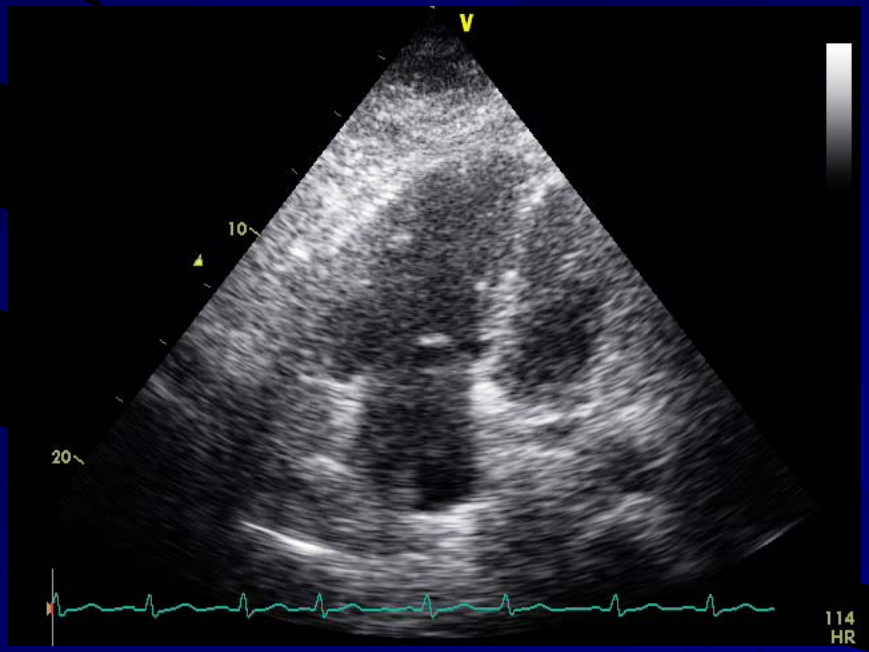
# Tricuspid Regurgitation

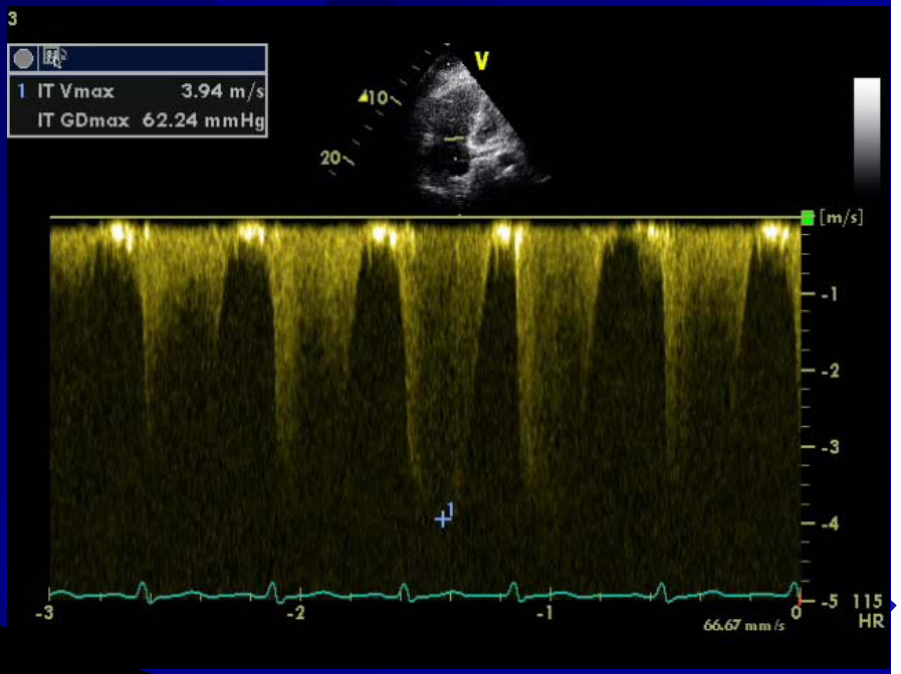



22
AP
8
VD
0 mm Hg
OD
MORPHOLOGIE DES COURBES DE PRESSION


PAPS ( 3PAPM – 2 PAPD ) = 12
3,7
2,6


CURSEUR +00000HZ -0200mS
TA
TA<100 ms = HTAP
CGR ULTRASONIC | 1.25S | 4KHZ


V
10
20
114
HR

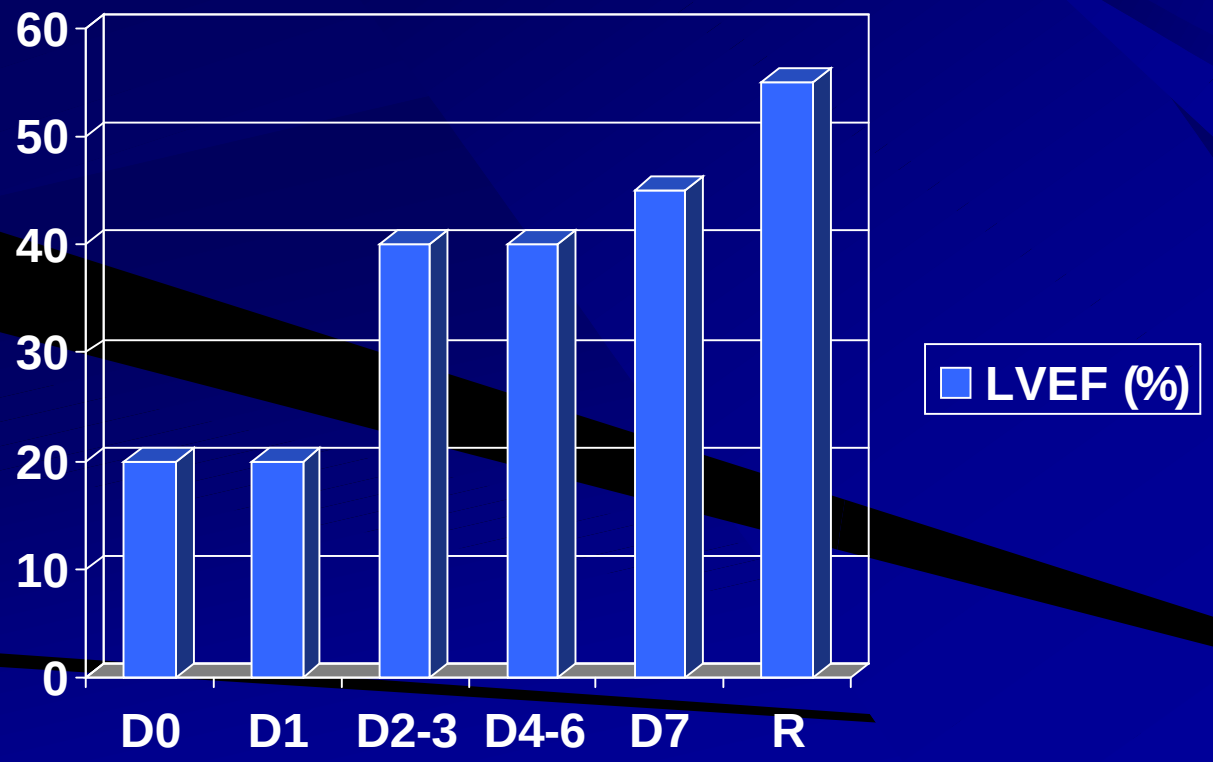

3
1 IT Vmax 3.94 m/s
IT GDmax 62.24 mmHg
V
10
20
[m/s]
-1
-2
-3
-4
-5
-3
-2
-1
0
66.67 mm/s
115
HR

# Résultats dans le choc septique

# Findings in septic shock patients

- Hypovolemia
- Hyperkinesic and hypokinetic shock
  - LV systolic dysfunction (<35-45%) in 30% (Groeneveld Int Care Med 1988) to 55% (Parker Ann Intern Med 1984) of septic shock.
  - EF 38% in patients 35% (AVB)
  - Recovery with normalization of LV (Parillo NEJM 1993)
  - Absence of dilation of LV (no early preload adaptation in echocardiographic study)
  - Norepinephrine in some cases may unmask LV systolic dysfunction

# LV systolic dysfunction

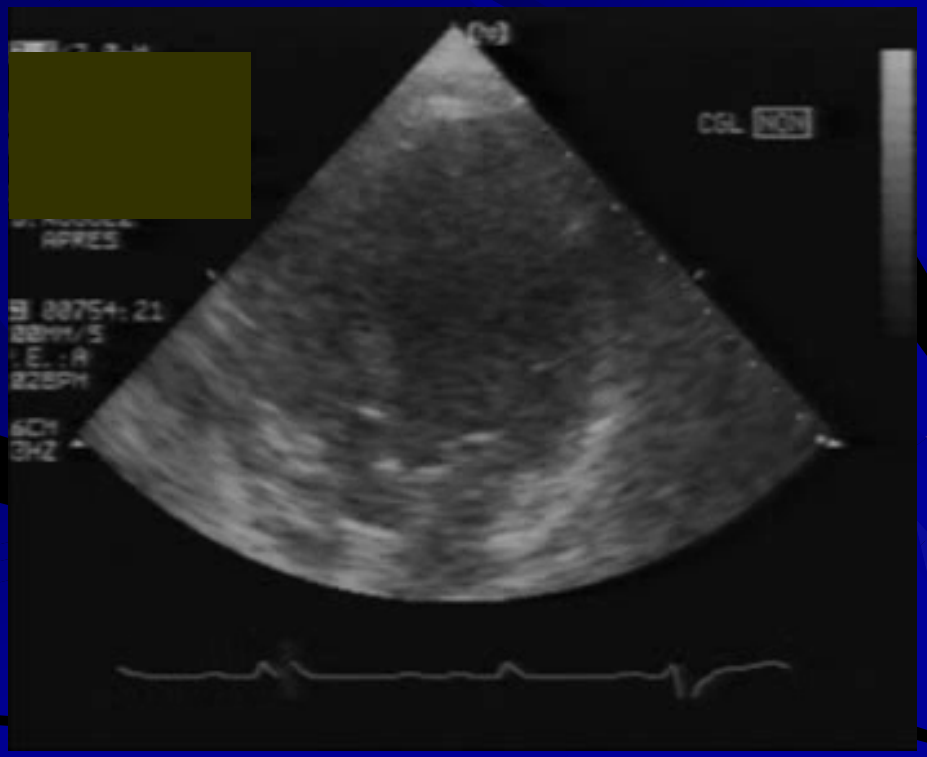



Vieillard-Baron AJRCCM 2003

# Findings in septic shock patients

- Cardiac output
  - High cardiac index (>3 l/min/m²) 65% of cases with EF of 65%
  - Low cardiac index (< 3 l/min/m²)
    - in 35% of patients (mean LVEF 38%)(Vieilard-Baron and Jardin)
    - Associated with hypokinetic condition
    - Dobutamine?

# Findings in septic shock patients



# Findings in septic shock patients

# Findings in septic shock patients

- Left diastolic dysfunction
- Right systolic dysfunction
  - Observed in 30% of patients (AVB)
  - Due to sepsis (intrinsic myocardial depression)
  - Increased by acute cor pulmonale (increased pulmonary vascular resistance)
  - RV dilation, paradoxal septum, PAPH.
  - Increased by mechanical ventilation with high PEP and tidal volume.
  - Dobutamine or norepinephrine?

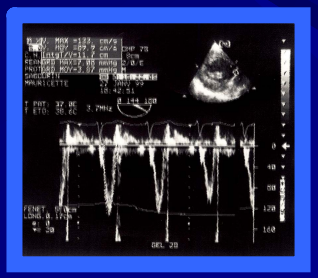
Etat de choc d'allure septique

Cathéter radial et Echocardiographie

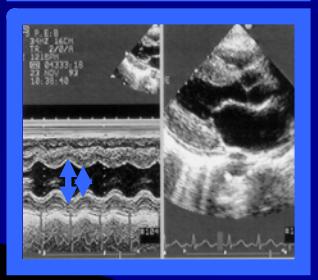
Variations respiratoires

Qc, PAPO

Oui : remplissage



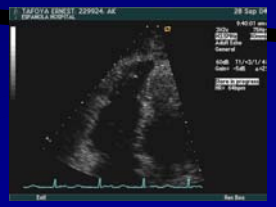
Non : Pas de remplissage



Evaluation de la fonction VG

Oui : Dobutamine

Non : NA

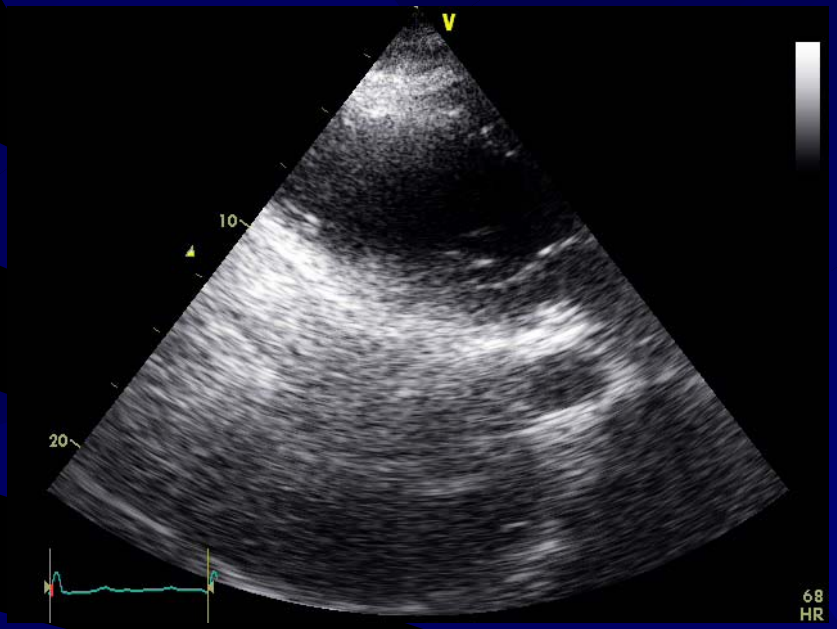


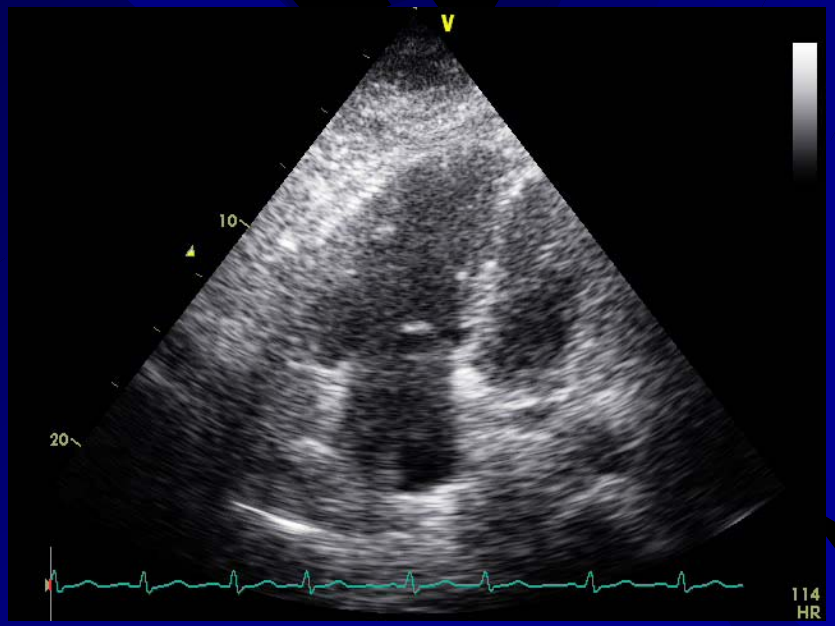
FE<40%

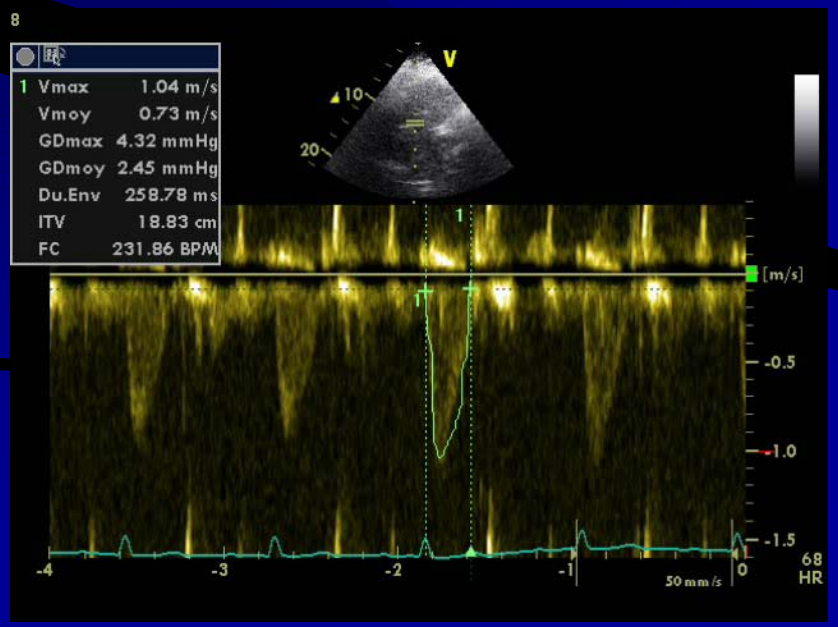
Evaluation de la fonction VD : CPA

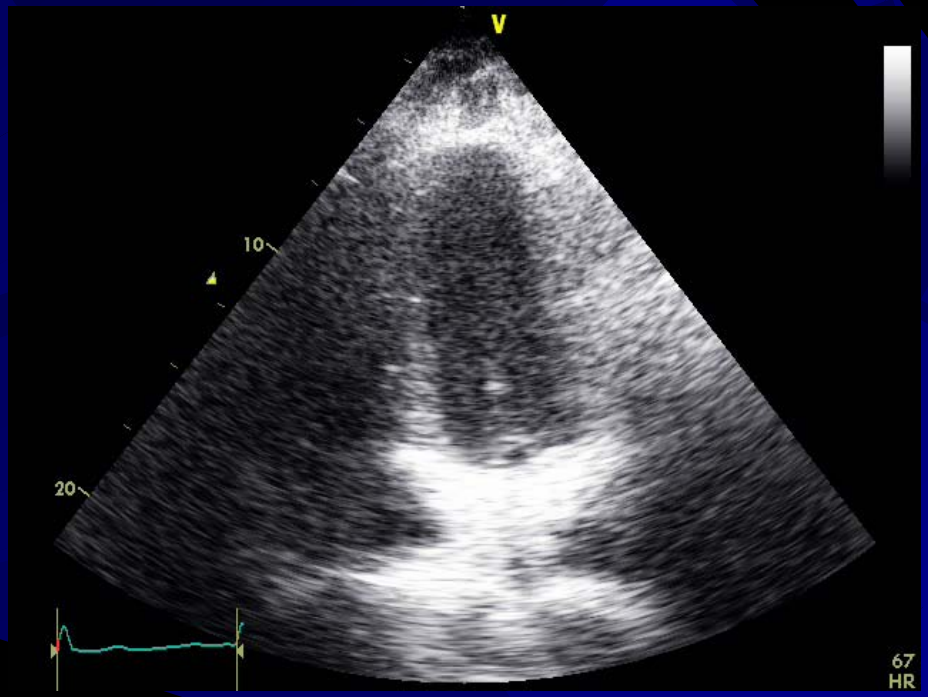
Oui : Réglage respirateur, NO, NA

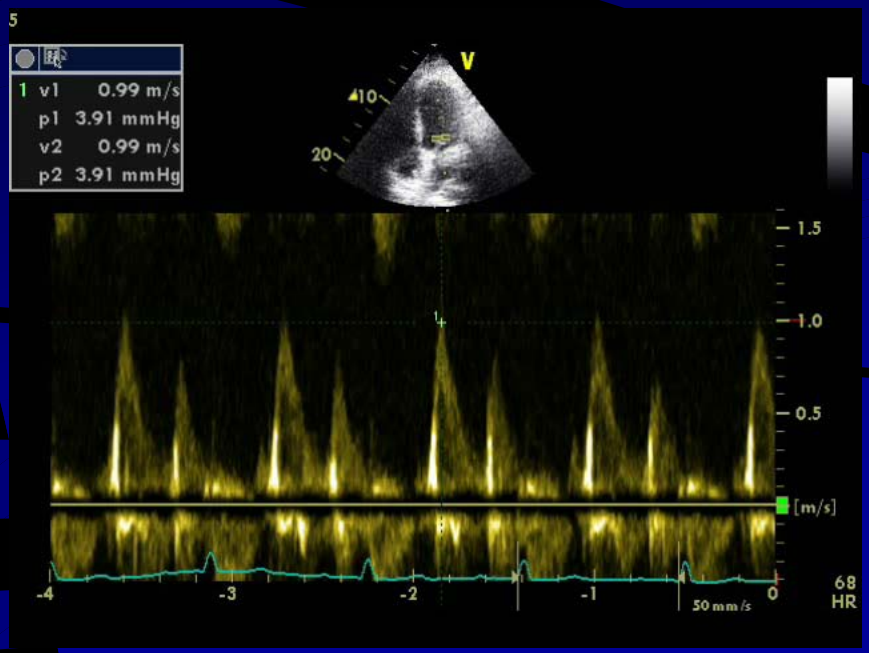
Non : NA

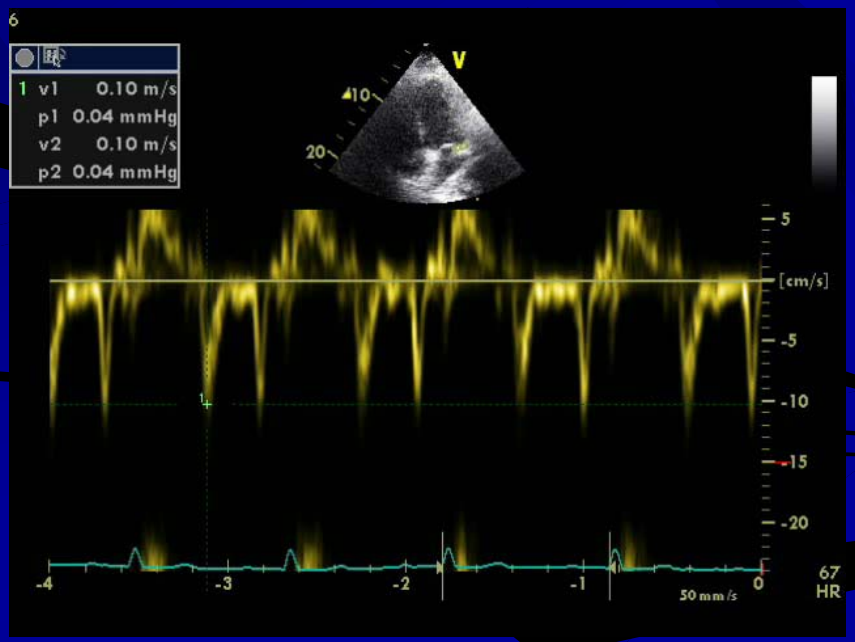

V
10
20
68
HR

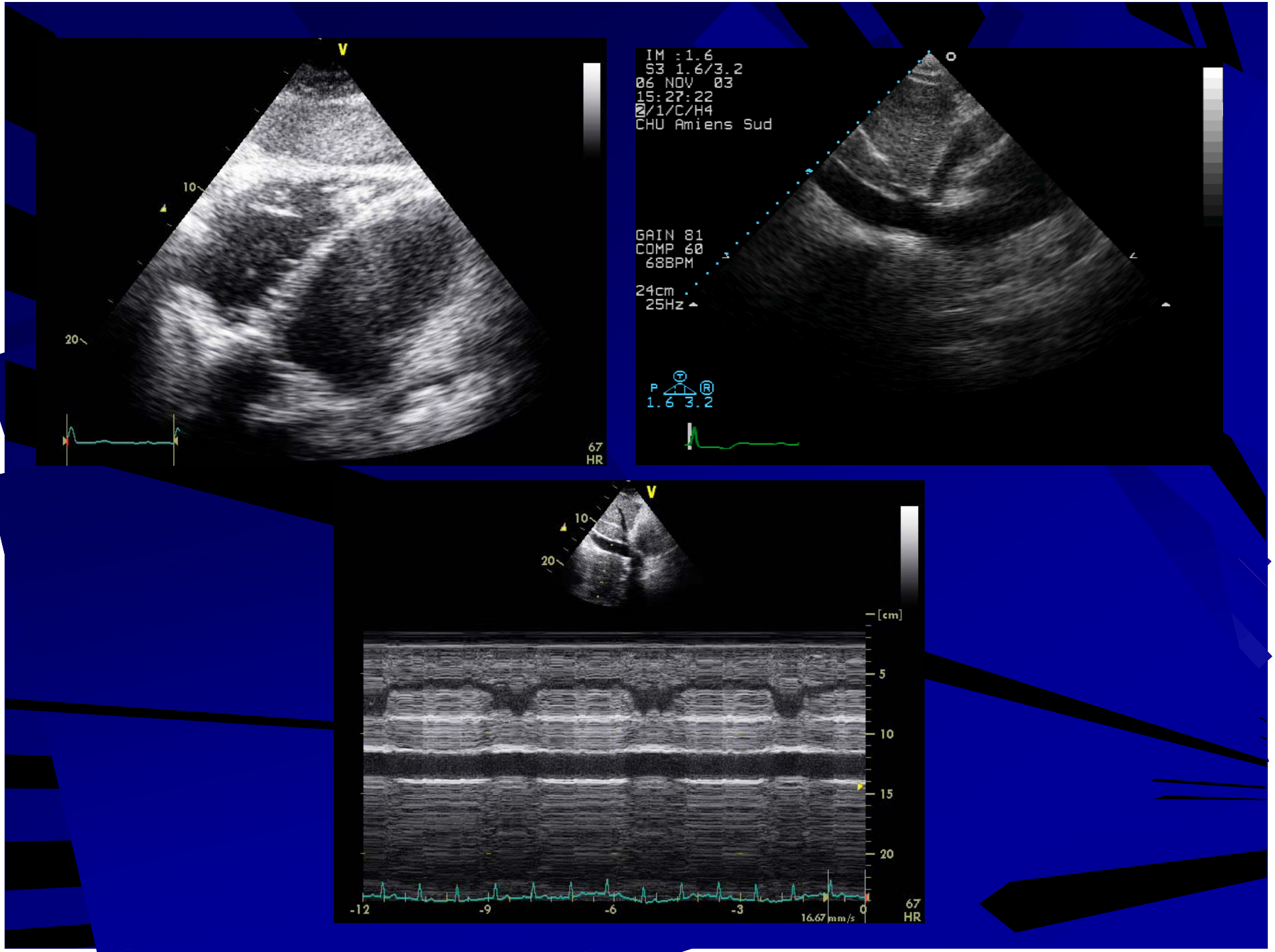

V
10
20
114
HR


8
1 Vmax 1.04 m/s
Vmoy 0.73 m/s
GDmax 4.32 mmHg
GDmoy 2.45 mmHg
Du.Env 258.78 ms
ITV 18.83 cm
FC 231.86 BPM
V
10
20
1
[m/s]
-0.5
-1.0
-1.5
-4
-3
-2
-1
0
50 mm/s
68
HR


V
10
20
67
HR


5
1 v1 0.99 m/s
p1 3.91 mmHg
v2 0.99 m/s
p2 3.91 mmHg
V
10
20
1.5
1.0
0.5
[m/s]
-4
-3
-2
-1
0
50 mm/s
68
HR


6
1 v1 0.10 m/s
p1 0.04 mmHg
v2 0.10 m/s
p2 0.04 mmHg
V
10
20
5
[cm/s]
-5
-10
-15
-20
-4
-3
-2
-1
0
50 mm/s
67
HR


V
10
20
67
HR
IM :1.6
S3 1.6/3.2
06 NOV 03
15:27:22
2/1/C/H4
CHU Amiens Sud
GAIN 81
COMP 60
68BPM
24cm
25Hz
P
1.6 3.2
V
10
20
[cm]
5
10
15
20
-12
-9
-6
-3
0
16.67 mm/s
67
HR

# Conclusions

- Septic shock
  - Cardiac output, ejection fraction, preload-dependance, right function and pressures should be assess.
  - Hypovolemia is constant
  - Systolic dysfunction of both ventricle is frequent without cavity dilation

# Impact thérapeutique de l'échocardiographie en USI


1. Vignon et al, Chest 1994
2. Pavlides et al, AHJ 1990
3. Pearson et al, AHJ 1990
4. Poaelert et al, Chest 1995
5. Hwang et al, Chest 1993
6. Heidenreich et al, JACC 1995
7. Sohn et al, Mayo Clin Proc 1995
8. Oh et al, AJC, 1990
9. Vignon et al, AJRCCM 1998 (Abst)
10. Benjamin et al, JCVVA 1998 (Abst)
11. Megarbane, Axler et al, Rea, Urg 99 (Abst)
12. Slama et al. Int Care Med 1998


TEE > TTE

24-48 % patients concernés

Intervention chirugicale dans 10-29% des cas

En période périoperatoire, changements thérapeutiques fréquents et majeurs

30-58% résultats discordants entre ETT/ETO et CAP

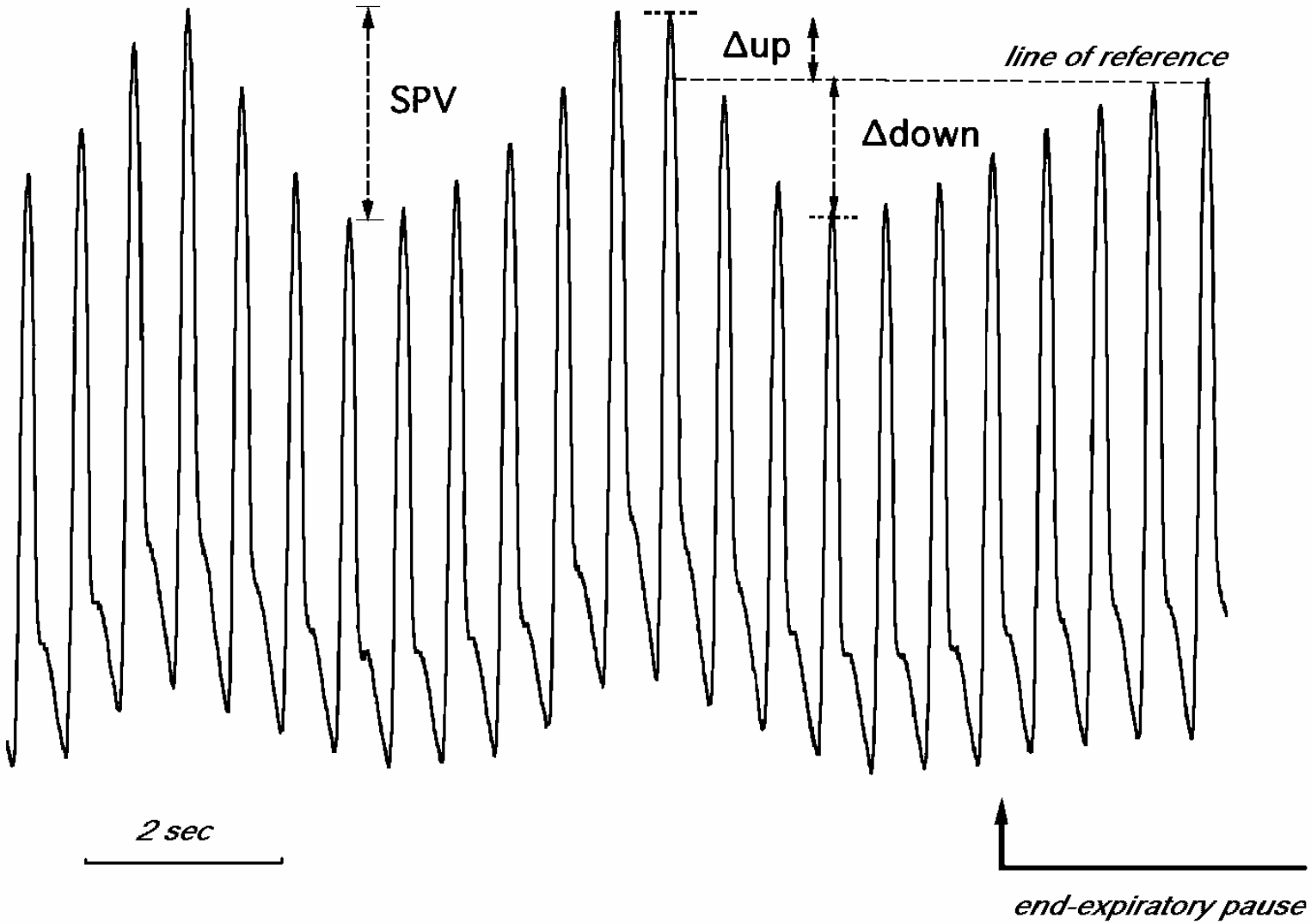
# Limitations of static values

| | 13 Pts | Pre Infusion | Post Infusion | |
|---|---|---|---|---|
| RAP | mmHg | 10.6 ± 2.9 | 12.4 ± 3.3 | ns |
| PAOP | mmHg | 13.1 ± 3.7 | 14.7 ± 3 | .002 * |
| MAP | mmHg | 79.7 ± 11.6 | 81 ± 12.4 | ns |
| H R | beat/min | 102 ± 25 | 101 ± 25.1 | ns |
| MPAP | mmHg | 27.7 ± 5.6 | 29.5 ± 5.4 | ns |
| CI | $l/min/m^2$ | 4.3 ± 1.7 | 4.6 ± 1.8 | ns |
| SI | $ml/m^2$ | 42.7 ± 12.7 | 45.3 ± 14 | ns |
| LVEDA | $cm^2/m^2$ | 8.6 ± 1.7 | 9.1 ± 1.8 | ns |
| LVESA | $cm^2/m^2$ | 3.5 ± 1.5 | 3.6 ± 1.5 | ns |
| SVRI | $dyne.sec.cm\text{-}^5/m^2$ | 1368 ± 473 | 1343 ± 489 | ns |
| PVRI | $dyne.sec.cm\text{-}^5/m^2$ | 327 ± 131 | 311 ± 142 | ns |

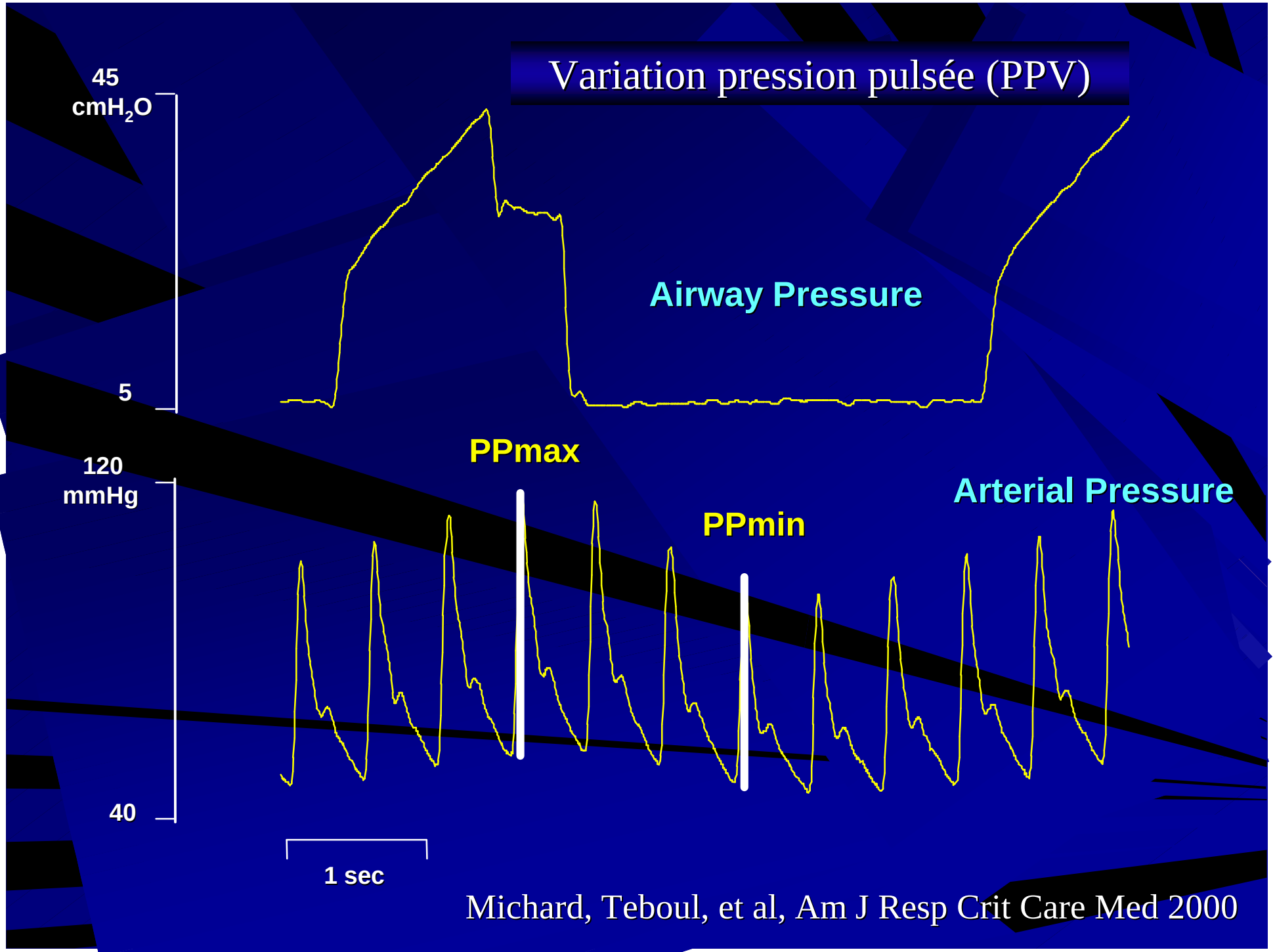
Effects of rapid fluid loading of 500 ml saline on hemodynamic and echocardiographic parameters in 13 critically ill patients.

Small hemodynamic effect of typical rapid volume infusions in critically ill patients.
O. Axler, et al. **Crit. Care Med**, 1997, 25: 965-970.

# Variation pression systolique (SPV)




Michard, Teboul et al, Am J Resp Crit Care Med 2000

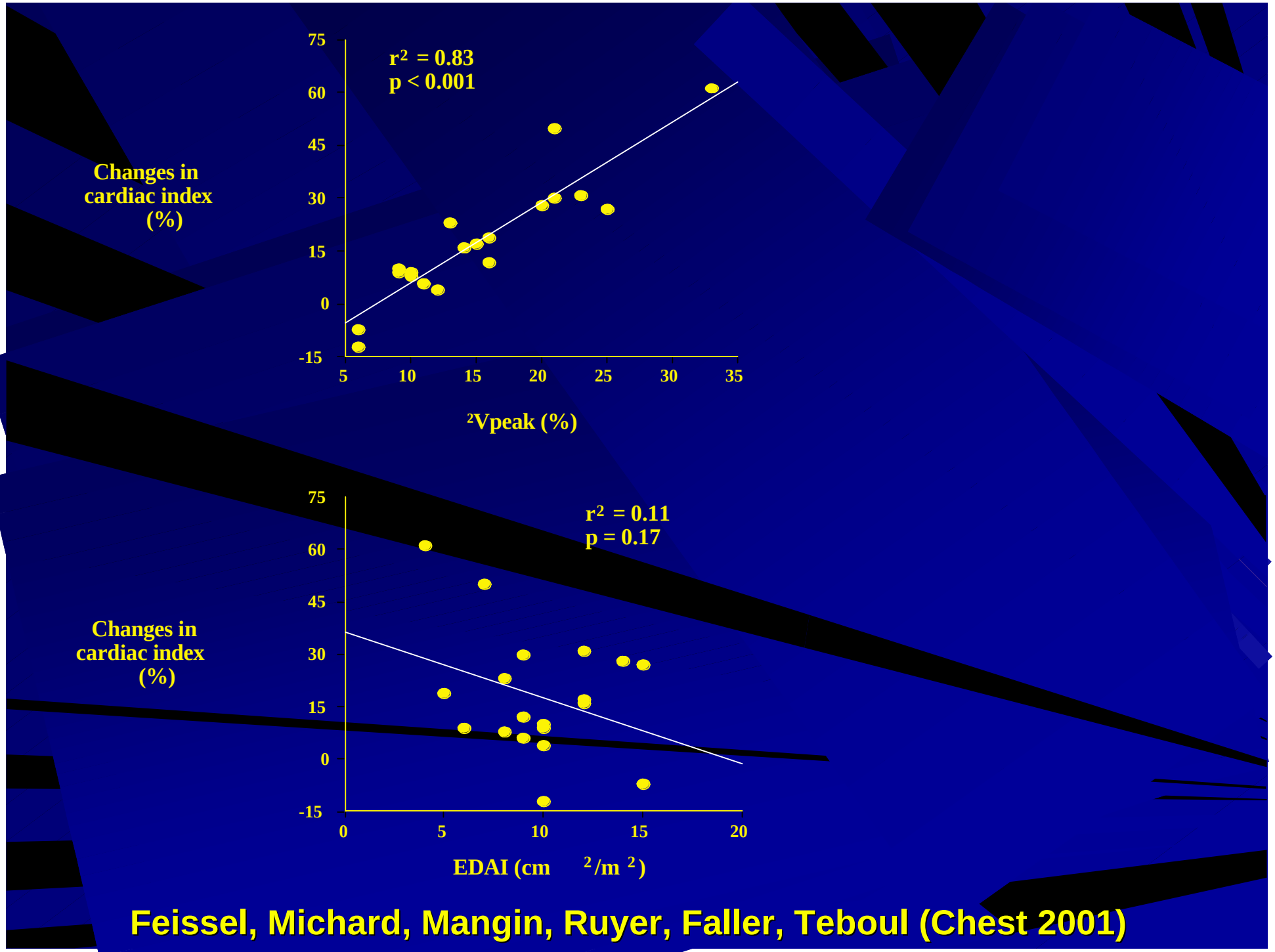



Michard, Teboul, et al, Am J Resp Crit Care Med 2000

# Variation pression pulsée (PPV)

$$\Delta PP\ (\%) = 100 \cdot \frac{PPmax - PPmin}{(PPmax + PPmin) / 2}$$

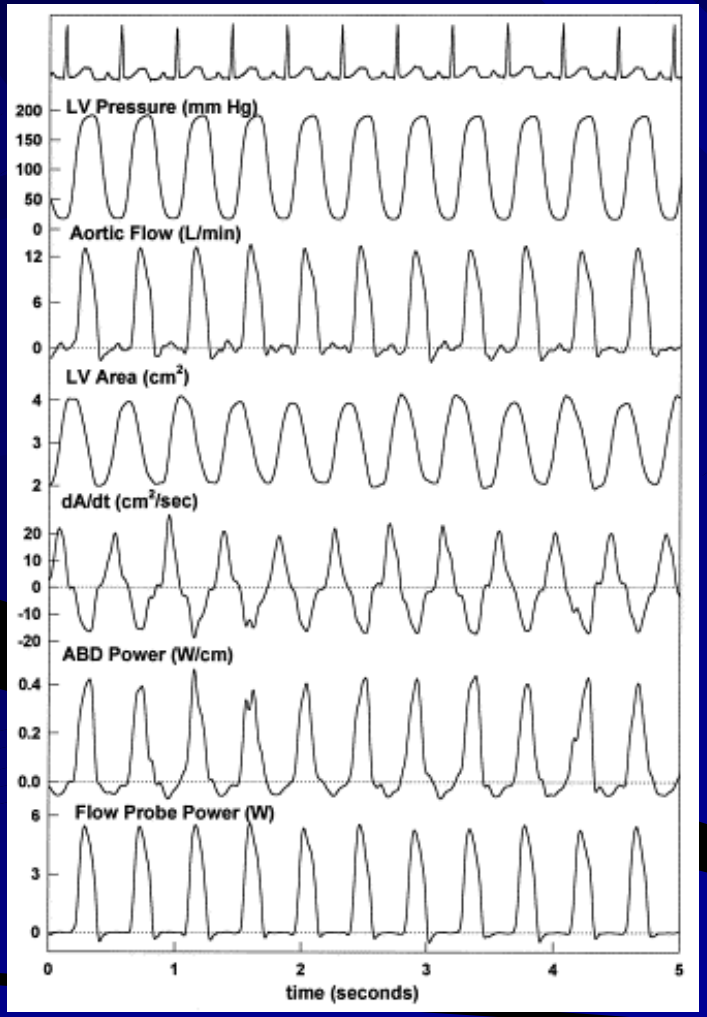
Michard et al, Am J Resp Crit Care Med 2000




**Feissel, Michard, Mangin, Ruyer, Faller, Teboul (Chest 2001)**

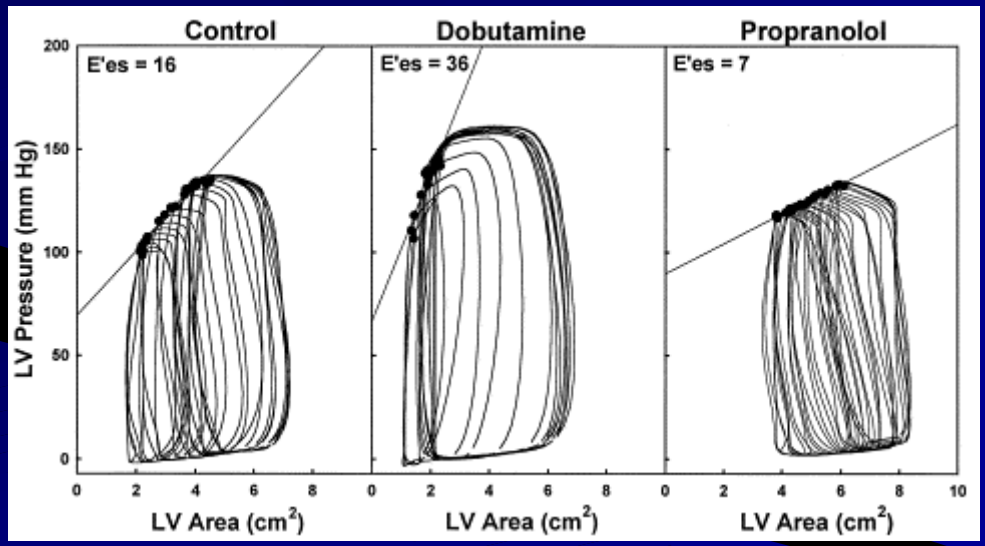
# Complications de l'ETO

- Ambulatoire :
  - Mortalité : 0,0098 (10218 patients, Daniel Circulation 1991)-0,026 (3827 patients, Seward JASE 1992)
  - Perforation oesophagienne : quelques cas (2 Amiens) entre des mains expertes.
  - Complications majeures : bronchospasme, tachycardie ventriculaire, insuffisance cardiaque : 0,2% (Seward JASE 1992;5:288) à 0,5 (Khandheria JACC 1991)
  - Complications mineures : 2,7% (Seward JASE 1992;5:288)




Takagaki M, Heart. 2002 Aug;88(2):170-6.

A sample plot of simultaneous
LV pressure, aortic flow, echocardiographic ABD cross-sectional area, dA/dt, ABD power and flow probe power.




Takagaki M, Heart. 2002 Aug;88(2):170-6.

# Echec d’introduction

**Mais ETO parfois difficile voire impossible dans 2-5% des cas : cause la plus fréquente inexpérience du manipulateur, mais aussi du à une anomalie anatomique (Daniel, Slama)**